

**BREASTFEEDING IN PREMATURE  
INFANTS:**

**A descriptive study**

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## **Declaration**

The studies presented within this thesis were carried out by myself under the guidance of Dr. R. Mander and Dr. I. Laing. I certify that this thesis has been composed by myself and does not contain material published or written by any other person except where due reference is made in the text.

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## **Abstract of Thesis**

Establishing breast feeding in the infant born prematurely remains one of the most important challenges to neonatal midwives. Many obstacles stand in the way of mothers becoming successful in this technique, probably the most notable being unit guidelines established through anecdotal rather than evidenced-based information. Difficulties arise in gathering "evidence" and this may in some part account for the lack of literature on breast feeding and the preterm infant.

Earlier studies indicate that breast feeding infants regulate feeding differently to bottle feeding infants but these qualitative data do not adequately describe feeding performance. A convenience sample of preterm infants was selected and variables associated with feeding measured. A pulse oximeter continuously measured heart rate and oxygen saturation pre, during and post feed, whilst feeding variables (sucking, swallowing and breathing) were monitored using pressure sensors and auscultation. The data were collected and stored in a computer using the Snapshot programme.

The findings of this study indicate that practice at feeding affects outcome, bursts become longer and pauses shorter, sucks and swallows/second increase with breaths/second being influenced by milk flow and swallow rate. Total feeding time is variable and not dependent on post menstrual age (PMA). Immature infants (infants of 31 weeks PMA) are able to coordinate sucking, swallowing and breathing and produce rhythmic bursts and pauses and possibly adapt feeding performance according to physiological status. Finally suckling does not

cause any obvious increase in heart rate and therefore cannot be considered as an energy consuming activity.



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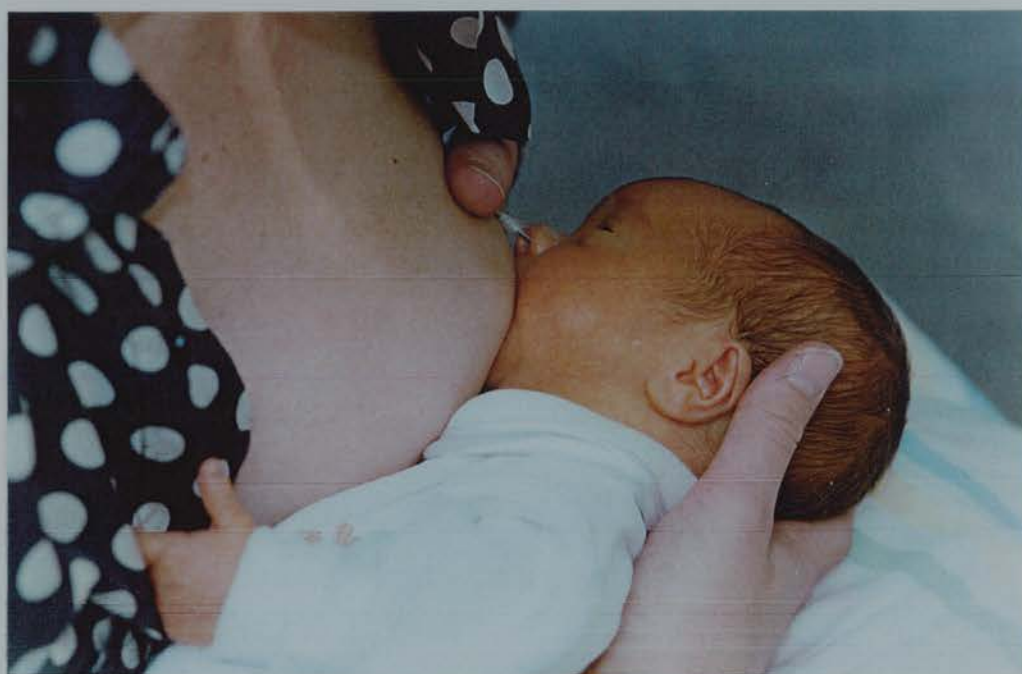
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# Definitions and abbreviations

<b>Caregiver</b>	Parent, Midwife, Nurse, Doctor
<b>Preterm</b>	Infants born less than 37 completed weeks of gestation
<b>PMA</b>	Post menstrual age (from time of conception to time of birth)
<b>O<sub>2</sub></b>	Oxygen
<b>CO<sub>2</sub></b>	Carbon dioxide
<b>TCPO<sub>2</sub></b>	Transcutaneous oxygen
<b>TCPCO<sub>2</sub></b>	Transcutaneous carbon dioxide

The pronoun "his" is used to refer to both male and female infants



Eilidh successfully breast feeding  
at 32 weeks post menstrual age

# **CHAPTER 1**



# Chapter 1

## *Introduction*

### *1.1 Background*

The human fetus reaches full maturity at 40 weeks gestation. Gestation being calculated from the first day of the woman's last menstrual period until the time of birth. During this time brain growth and development is not only influenced by genetic information but also by the health and well being of the mother (Naeye, 1992). Although growth and development continues throughout infancy and is dependent upon the type of nutrition and stimulation the infant receives (Lucas, 1994; Becker, 1991), the transition from intra-uterine to extra-uterine life in the normal full term infant has very little impact on its maturation. However in the event of a premature birth, brain growth and development may be compromised by immaturity in structure and function as a considerable amount of neuronal growth and differentiation continues to occur without the support of the intra-uterine environment and feto-maternal placenta (Field, 1990; McCormack, 1990).

The newborn infant progresses from maternal nutrition offered via the placenta to enteral nutrition as supplied through breast or formula milk. Nutrition in terms of calories, protein, fat, carbohydrate, vitamins, minerals, trace elements and water may therefore be provided to the preterm infant through either feeding method. However artificial milk is essentially inert with constituents being modeled after human breast milk, whereas breast milk is a living substance; it is species-specific and

contains nutrients, enzymes and hormones which are specific for brain growth and which may compensate for the deficiencies in gut function imposed through immaturity (Leaf, 1996, Weaver, 1996). However many obstacles stand in the way of women who have delivered a premature infant in initiating and maintaining lactation.

## ***1.2 Potential parenting problems associated with prematurity***

The relationship between parent and baby does not begin at birth but rather during pregnancy where realisation is predominant after quickening (Rubin, 1984). However nothing truly prepares a person for the changes which occur; becoming a parent brings emotions which are labile, swinging from awe and amazement to fatigue and a sense of overwhelming responsibility for the well-being of the new baby (Bull, 1985). In addition prospective parents need time to adjust themselves to the new and very different role they will establish within their society. Thus the transition to parenthood has been likened to a life crisis (Miller, 1980).

Much of the preparation for parenthood takes place during the last trimester of the prenatal period. However the birth of a premature baby denies parents this opportunity and they are therefore disadvantaged in their planning. Furthermore the admission of an ill baby to a neonatal intensive care unit exacerbates the "crisis" of parenting by increasing the feelings of anxiety and grief, guilt and fear (Stjernquist, 1992; Steel, 1987). This abnormal situation is often complicated as parent and baby are frequently separated for long periods of time. This instils a lack of

confidence and feelings of inadequacy. In particular mothers experience great anxiety about feeding their infant.

Neonatal intensive care units have tried to address the problems of separation. Family centred care and encouragement of active participation by parents in the planning and delivery of their infant's care is included in the philosophy of many units. Parents are encouraged to be with their baby but the amount of intensive care and support given to sustain life often means they are afraid to touch their baby or carry out normal parenting activities. Thus amongst the milieu of technology, the emotional and social needs of parent and infant are frequently unfulfilled. There are however occasions when normal biological functioning can assist parents in developing a relationship with their baby. By encouraging and enabling parents to provide expressed breast milk for their baby, carers can promote parent-infant interaction and offer infants the best in nutrition and health (Taylor, 1985).

### ***1.3 Beliefs and practices related to infant feeding***

The advantages of breast milk to maternal and infant health and well-being are widely known and accepted (Williams, 1994). Breast milk is the most easily digested form of milk. The composition varies from colostrum in the first days of feeding to mature milk after a few weeks. There are also variations within a feed and a 24 hour period thus meeting the specific needs of the infant from delivery until well into infancy. Breast milk contains immunoprotective components which increases an infant's chance of protection from many common ailments and particularly within

the neonatal intensive care unit from necrotising enterocolitis (Lucas, 1990).

Breast milk also contains growth factors which not only help maturation of the gut but also promote absorption of other growth factors and hormones (Lucas, 1980, Grosvenor, 1993). Although artificial milk contains many nutrients essential for growth it does not have the long chain polyunsaturated fatty acids as seen in breast milk. These are mostly deposited within the membranes of the developing brain and retina and are associated with improved neurodevelopmental outcome (Leaf, 1996).

In addition to the immediate beneficial effects of breast feeding long term studies suggest that the incidence of juvenile diabetes in predisposed infants is reduced, as is Crohn's disease and childhood lymphoma (Virtanen, 1994, Koletzko, 1989, Davis, 1988). Breast feeding has been associated with high cholesterol levels during infancy but lower during later life; the mechanism for this is poorly understood (Wong, 1995). For the mother, breast feeding has been associated with a decrease in incidence of pre-menopausal breast and ovarian cancer and is considered to be one way in which role adjustment may be improved.

For these reasons it is mutually beneficial to encourage and support breast feeding for all infants. However lack of knowledge, understanding and consideration has hindered premature/ill infants and their mothers from being successful in achieving full breast feeding. Professional education in oral feeding has been lacking and it is only in recent years that mothers' views of breast feeding in the neonatal unit have been

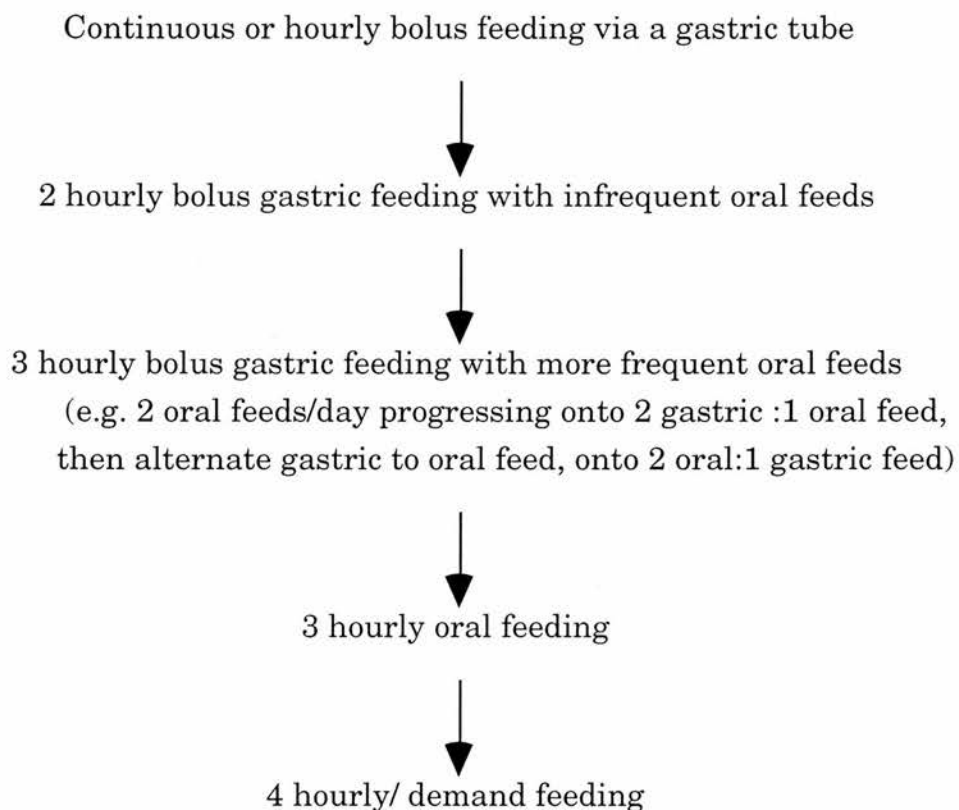
investigated. It is not surprising that neonatal unit guidelines on feeding practice are based on anecdotal evidence and intuition. Increasing awareness of the benefits of breast feeding has brought about some changes to practice. In many units temperature control and weight are no longer considered criteria for commencing oral feeds. Successful bottle feeding is no longer essential for allowing breast feeding. However gestational age remains a significant factor with few units beginning oral feeds before 34 weeks post menstrual age.

Even though there is an awareness of difference in the mechanisms between breast and bottle feeding, there appears to be no difference in criteria for commencing or progressing with oral feeds. Oral feeding, especially breast feeding, is said to be very tiring and possibly stressful for premature infants and often more difficult than bottle feeding. It is also said that when commencing oral feeding, one has to limit the frequency of feeding and the time allowed per feed so that the energy expended in feeding does not exceed that gained in nutritive sucking. The reasons for these beliefs and practices are difficult to establish; no reference could be found which supports them.

## ***1.4 Oral feeding***

The ability to nutritively suck necessitates functional anatomy, physiological stability and mature neurodevelopmental skills and is an important sensory experience (Shaker, 1990). If carried out at an inappropriate time when infants may be unable to integrate sucking, breathing and swallowing in a coordinated manner or through behavioural strategies control the stimulation they receive, severe

physical and developmental consequences may occur e.g. aspiration, hypoxia, cardiovascular instability and oral defensiveness. Because of variations within the infant population the ability to feed successfully is an individual skill with some infants experiencing great difficulty in mastering the technique. This aspect of caring then becomes frustrating and demoralising when it should be a pleasant and rewarding experience for all concerned. The flow chart (figure 1) shows the progression from gastric to oral feeding in one neonatal unit. Three methods of oral feeding are utilised in this unit, breast, cup and bottle feeding. Cup feeding is most often used to supplement breast feeding (page 42).



*Figure 1* Progression from gastric to oral feeding

## ***1.5 Rationale for the study***

By imposing restrictions on when to commence oral feeding and how often and for how long infants are able to suckle, mothers are placed under great pressure to initiate and maintain lactation through abnormal means. This may affect both the amount and quality of milk produced and for women who have very little milk or a diminishing supply, it can be demoralising and counterproductive.

One purpose of research is to develop theories which establish the association between client need and outcome and care interventions (McFarlane of Llandaff, 1991). Therefore a better understanding of the mechanics of breast feeding in infants admitted to a neonatal unit may help caregivers effectively influence and thus improve health and well-being in these families.

This thesis describes the organisation of breast feeding in premature infants and considers the contribution the results may have on the body of knowledge and provision of care.

Following the introduction which explains the background to the study, the thesis continues with the literature review (chapter 2), outlining the mechanisms of oral feeding in well term infants. The factors which influence feeding ability are drawn from this outline and discussed more fully in relation to fetal development and the consequences premature birth may have on them.



Many studies have demonstrated the effects of environmental stimulation on physiological parameters and neurodevelopmental systems but few have offered a theory within infant development which explains the repertoire and significance of individual responses (Cooper Evans, 1991; Long, 1980 a & b; Downs, 1991). Therefore the theoretical framework has been constructed from a tool which assesses feeding ability utilising a theory of infant development which explains the relationship between physiological control and stability and neurodevelopmental outcome (chapter 3).

Research methodology is outlined in chapter 4. The assumptions of caregivers are addressed in chapters 5 to 8; each presenting data and discussion of the findings. The final chapter of the study brings together the issues which emerged from the data and highlights the role of a researcher in the clinical setting.



## **CHAPTER 2**

# Chapter 2

## LITERATURE REVIEW

### 2.1 Mechanisms of feeding

#### 2.1.1 *Functional development*

The functional requirements of oral feeding largely depend on the infant being able to suck, swallow and breathe safely and co-ordinately in a skilful sequence (Stevenson, 1991). The quality in performance of these three processes intricately involves functional anatomy, neural control and maturational influences (Wolf & Glass, 1992). Selley, (1990, p.326) concludes that normal feeding requires “rhythmic breath control, lip tone, delicate tongue movements, speed of muscle movement, well developed sensory feedback mechanism and a relaxed situation.”

The well term infant is born with the developmental skills of locating and latching onto the nipple and safely sucking to obtain nourishment. Inherent in these abilities is the presence of primary reflexes. These may be divided into adaptive and protective reflexes (Wolf & Glass, 1992).

#### 2.1.2 *Rooting*

The rooting reflex is necessary to develop oral motor skills as it helps the infant locate the source of nourishment. From 8 weeks gestation, receptor cells are present in the peri-oral region and ultrasound studies have been

able to show mouth opening responses to stimulation from this time with thumb sucking from 16 weeks gestation (Iannirnberto, 1981). Thus a primitive rooting reflex is seen early in development. Rooting is more essential in breast feeding where, coupled with a suck reflex, the infant locates and fastens the nipple in his mouth. In bottle feeding this action is unnecessary as the caregiver inserts the bottle teat into the infant's mouth and therefore the act of rooting and latching is not crucial to the feeding process.

### **2.1.3     *Sucking***

The skill of sucking develops in-utero as the fetus responds to sensory and proprioceptive stimuli (Humphrey, 1965). Nutritive sucking involves two rhythmical components, suction and expression. Suction involves a negative pressure mechanism whereby milk is 'drawn' out of the teat or nipple. Expression utilises positive pressure to compress the teat or nipple to 'push' milk out (Brake, 1988). Gryboski (1969) and Morris and Klein (1987) describe a 'lick / lapping' mechanism as an initial or immature component of sucking. This mechanism involves protrusion of the tongue to just beyond the lip border. With a reverse action the tongue strips milk from the teat or nipple. This licking/lapping action is accompanied by active up and down jaw movements and poorly sealed lips.

In mature sucking the tongue forms a central groove (in the antero-posterior direction) helping to stabilise the nipple and direct the milk bolus towards the pharynx. Together with the lips it forms a seal around the nipple and posteriorly rests against the soft palate so creating a

chamber. The sucking mechanism requires the anterior portion of the tongue to compress the nipple against the hard palate so expressing milk and then the posterior portion of the tongue is lowered and because of the seal, creates negative pressure and so draws milk into the mouth. The action of the tongue appears to be piston-like in bottle fed infants and rolling peristalsis in breast fed infants (Weber, 1986, Smith, 1988).

The jaw provides stability by giving shape to the oral cavity and a base for muscle attachment to facilitate movement of other structures. The cheeks are equally important as they provide the lateral boundaries of the oral cavity. The fatty buccal pads aid stability and assist in the production of negative pressure (Morris & Klein, 1987).

#### **2.1.4 Breathing**

Although feeding and breathing belong to different physiological systems, the close proximity of anatomical structures makes the processes intimately related.

The purpose of the respiratory system is to maintain a balance between oxygen ( $O_2$ ) and carbon dioxide ( $CO_2$ ) in the blood in order to meet the metabolic needs of the infant. Achievement of this purpose relies on effective structural and sensory feedback mechanisms. The internal structures of respiration include:

- a) conducting airways - nose, mouth, pharynx, larynx, trachea, bronchi and bronchioles,
- b) the alveoli with air-fluid interfaces.

The external structures include:

- a) rib cage,
- b) chest wall with accessory muscles,
- c) diaphragm and
- d) abdominal muscles.

Breathing is possible because the lungs and chest wall have elastic properties, and compliance is achieved by surfactant. Energy expenditure related to breathing depends on the rate and depth of respiration, lung compliance and resistance to airflow by the conducting airways. The sensory feedback mechanism relies on chemo-receptors to provide information on  $O_2$  and  $CO_2$  levels. Stretch receptors provide information on the volume of gas in the lungs and the resistance to flow of gas through the passages.

The respiratory system has a number of mechanisms by which effective ventilation may be achieved. The rate, rhythm and depth of respiration may increase or decrease. These three mechanisms can work independently or collectively in order to increase or decrease the exchange of  $O_2$  and  $CO_2$ . Heart function may also alter to meet changing needs. Sensory information from chemo-receptors located in the aortic and carotid bodies respond to changes in partial pressure of  $O_2$  and  $CO_2$ . In general respiratory drive is mediated by changes in  $CO_2$  levels. The value at which  $CO_2$  initiates an alteration in respiratory effort is relatively low. However sensitivity also appears to be different depending on the temperature of the environment.

Although chemo-receptors appear primarily to alter the level of respiration, stretch receptors regulate the pattern of breathing. Stretch receptors are sensitive to the degree of lung expansion and have an inhibitory effect to prevent over inflation and complete deflation. They operate via the vagus nerve in the respiratory centre.

As a consequence of premature birth, the infant has had insufficient time to develop adequate chest and abdominal muscle fibres. This coupled with a poorly ossified rib cage makes the chest wall highly flexible and therefore inefficient at generating negative intrathoracic pressure. Instead of an upward and outward movement, the chest wall caves inwards reducing thoracic space. The infant therefore must also use accessory muscles of respiration to achieve adequate intake and exchange. The poorly defined muscle fibres and diaphragm reduce elastic recoil - the natural tendency of stretched structures to return to their natural state - which is the passive movement of expiration. As a result the infant must use abdominal muscles to force expiration.

The premature neonate is further disadvantaged. He must overcome lung stiffness which results from a lack of surfactant. This substance reduces surface tension thereby aiding alveolar expansion. However the constituents of surfactant are not produced in the optimum ratios until after 32 weeks gestation. Airway resistance also contributes to the work of breathing. The greater the resistance the higher the pressure required to drive gas through. The size of the premature infant mitigates towards tiny conducting passages and therefore increases the effort of breathing.

Premature infants are further compromised by their response to  $O_2$  and  $CO_2$ . They have a flattened  $CO_2$  response curve and during normal respirations are slower at initiating an increase in respiratory effort in response to rising  $CO_2$  levels than are term infants. When experiencing periodic breathing or apnoea, they are even less sensitive to rising  $CO_2$  levels. They also have a selective sensitivity to changes in environmental temperature. In a warm environment hypoxia will induce an increase in respiratory rate and depth in the premature infant. Following the initial exertion of hyperventilation, periodic breathing and apnoea may occur. In a cool environment there is no increase in rate or depth of respiration. Periodic breathing is the consequence of hypoxia.

The combination of these factors increases the work of breathing. During periods of increased exertion or stress the muscles involved may become overly fatigued and unable to sustain the effort required to maintain adequate gas exchange. Not only is the premature infant disadvantaged by fragility but also by poor organisation of the respiratory control centres within the brain. Apnoea of prematurity is a condition which only affects premature infants and for which the infants will grow out of. It resolves through maturation of the central nervous system.

Thus the infant must have in place a number of structures and mechanisms by which normal respiration may take place prior to the inhibition of breathing by frequent and repetitive swallowing. In relation to the development of oral motor skills, the infant must further develop protective mechanisms and reflexes. The most effective reflexes are those that maintain free air flow through the upper airway and prevent

aspiration causing inflammation or infection of the lower airway. These reflexes and mechanisms include: gag, cough and swallow.

### **2.1.5    *Swallowing***

Swallowing as a reflex occurs in conjunction with fluid in the mouth. It has been observed on ultrasound at 12 to 14 weeks gestation (Inniruberto, 1981) and contributes to the production and regulation of amniotic fluid.

The action of swallowing is completed in three stages: the oral, the pharyngeal and oesophageal. Because of the complexity of the process, it is a combination of voluntary and involuntary actions. The first stage (almost exclusively that of sucking in the infant) is the backward projection of milk through the tongue groove to the pharynx. The milk bolus reaches the posterior pharyngeal wall and the second stage is initiated. As the swallow is activated, the soft palate rises and the posterior pharyngeal wall constricts. These two actions close off the airway. Additional protection of the airway is provided by the constriction of the vocal cords. The milk bolus moves through this channel by peristalsis and a change in pressure gradients. The third stage commences as the bolus moves past the closed airway; the cricopharyngeal muscle relaxes and the oesophagus opens. Once in the oesophagus peristaltic action propels the milk bolus to the stomach (Tuchmann, 1988; Logeman, 1983; Woolridge, 1986).



### **2.1.6     *Gag and cough***

The gag reflex has been observed in the fetus from 18 weeks gestation (Tucker, 1985) and coughing in the infant from birth. The larynx contains many receptors that are able to function in a number of ways to protect the airway. The most common response to chemical stimuli is to close off the airway as previously described and initiate a swallow. This occurs during feeding. Chemical and mechanical stimulation from introduced fluids, oral secretions, gastric acid or touch can elicit gagging and coughing. Vomiting may follow this.

Humphrey (1965) describes the fetal development of reflexes which are necessary for succesful oral feeding following birth. These are summarised in table 1.

Post menstrual age (weeks)	Stimulation	Action	Involvement
7.5	perioral	CLF	cervical, upper thoracic
8	perioral	CLF	cervical, thoracic & lumbosacral
8.5	perioral	CLF	as above & extension of arms at shoulder level soles of feet separate slightly
8.5-9	perioral	CLF	as above & pelvic rotation, hands pulled downwards, mouth uncovered; mandible actively lowered, midline opening of mouth with passive return to closure
9	perioral	CLF	asymmetric movement of upper & lower extremities, hands flex, digits spread apart
9-10	perioral	CLF	increased movement of pelvis & extremities, fully opened mouth
10	perioral	CLF & ILF	combination of movements
10-11	ophthalmic fibres	CLF & LR	squint & scowl
11	perioral & non oral	CLF & ILF	reflex closure of mouth
11.5	perioral	ILF	full mouth opening
12-12.5	perioral	ILF & LR	swallowing & tongue contraction

Table 1 Fetal development of reflexes associated with feeding (continued)

12.5	perioral, foot forearm & eyelid	LR	reflex opening and closing of mouth, leg kick of side stimulated
13	variation in stimulation	LR	swallowing reflex with partially opened mouth, isolated respiratory contractions
14	palm, eyelid back	LR	mouth opening with tongue action, lip elevation, swallowing with mouth closure & then reopening, squint & sneer, inspiratory gasp with flattening of diaphragm.
15.5	lip & tongue	LR	mouth open & closing with groove in tongue
15.5-17	taste buds	LR	
17	upper lip	LR	protrusion of upper lip
18			thumb sucking without lip puckering
18,5	tongue & pharynx chest	LR	gag reflex, chest contractions
20	lip	LR	upper lip puckering, lower lip protruding
22	lip diaphragm	LR	both lips pucker & protrude contraction & hiccups
24	oral	LR	sucking reflex

Table 1 Fetal development of reflexes associated with feeding

Abbreviations: CLF - contra lateral flexion, ILF - ipsi lateral flexion, LR - local reflexes

### 2.1.7 *Neural control*

Without central and autonomic nervous system control and organisation, the three elements of the feeding cycle sucking, swallowing and breathing, can not be accomplished. The sensory and motor functions of the cranial, cervical and thoracic nerves overlap to bring about co-ordination of these elements (table 2).

<u>Stages</u>	<u>Structures</u>	<u>Activity</u>	<u>Neural control</u>
<b><u>Rooting</u></b>	nose, cheeks, lips	head turns, jaw lowers.	Sensory-CN V.
<b><u>Sucking</u></b>	lips & oral cavity	lips close around the nipple, groove formation, elevation with posterior movement.	Sensory-CN V,VI Motor- CN V,VII
<b><u>Swallowing</u></b>	a.soft palate & larynx	elevation of soft palate, contraction of pharyngeal constrictures, larynx closed.	Sensory-CN V, IX Motor-CN V, VII X, XII. C 1-3.
	b.oesophagus	contraction of cricopharyngeal muscle, peristalsis.	Sensory-CN X. Motor-CN X
<b><u>Breathing</u></b>	lungs, diaphragm	inspiration, expiration, airway closure	Sensory-C X, IX Motor-CN X, C 3.

Table 2 Neural control of feeding

### **2.1.8     *Summary***

Successful oral feeding requires co-ordination of three complex functions: sucking, swallowing and breathing (Harris, 1986, Bosma, 1986). In addition, level of arousal, satiation and or drowsiness, taste and temperature of the fluid affect feeding outcome (Mathew, 1991). The well term infant is most often born fully prepared, having structural and functional anatomy and physiology and behavioural awareness competently to perform these functions.

## **2.2 Organisation and effects of oral feeding in well term infants**

### **2.2.1 *Bottle feeding***

Two phases of nutritive sucking have been described in the normal term infant:

- a. Wolff (1968) describes nutritive sucking as a continuous stream of sucking with no segmentation until near the end of feeding when irregular episodes of non sucking occurs.
- b. Mathew (1989) and Koenig (1990) describe nutritive sucking as an initial continuous burst of sucking which may last for up to two minutes and then followed by intermittent bursts of sucking and pausing.

Co-ordination of the suck, swallow and breathe mechanism has been well documented (Weber, 1986; Koenig, 1990; Bu'Lock, 1990; Selley, 1990). The frequency ratio between sucking and swallowing is initially 1:1 during the continuous sucking phase with the frequency of sucks and swallows varying between 40 and 70 per minute. Sucking pressure has been reported to be as high as  $213 \pm 74$  cm H<sub>2</sub>O (Mathew, 1989). Towards the end of feeding this changes to a 3:1 ratio. As well as a reduction in suck and swallow frequency, there is also a reduction in the pressure generated per suck (Mathew, 1989). In non- nutritive sucking the suck:swallow ratio is as great as 6:1 even though oral secretions are produced in response to the stimuli (Wolff, 1968). It is speculated that the size of the bolus created through sucking frequency and pressure affects the swallowing rate. The decline in nutritive sucking frequency and

pressure during a feed may result from satiation or fatigue, thus necessitating more sucks to achieve a large enough milk bolus to initiate a swallow (Harris, 1986).

The literature does not support breathing occurring simultaneously with sucking or swallowing. Rather during rhythmical, co-ordinated feeding, there is continuity in breathing as it occurs in synchrony with sucking and swallowing. However during nutritive sucking the upper airway is occluded by the epiglottis to prevent inhalation of milk but this protective action frequently results in bradycardia, change in colour and periods of ventilatory compromise where infants may desaturate with or without apnoea (Mathew, 1985 & 1989; Bamford, 1992; Koenig, 1990).

The relationship of swallowing and breathing is such that with each swallow there is cessation of airflow. Debate continues as to where in the respiratory cycle swallowing occurs. Selley (1990) has shown in term bottle feeding infants of between 8 hours and 6 days old, swallowing occurring after inspiration and prior to expiration, after expiration and prior to inspiration and finally in between two expiratory phases. Bamford (1992) describes nine possible sequences in which swallowing may occur with the most frequently occurring sequence being inspiration-swallow-expiration. Weber (1986) on the other hand reports 2 day old infants swallowing prior to inspiration and expiration but in the 5 day old infant, it occurs only after expiration.

Koenig (1990) reports respiratory compromise with some total obstruction lasting approximately 600 msec beginning about 200 msec prior to the initiation of a swallow. Apart from airway obstruction a reduction in

minute ventilation was seen. Minute ventilation was affected by a reduction in both respiratory frequency and tidal volume. Changes to the respiratory cycle, that being a reduction in inspiratory time and an increase in expiratory time have also been reported (Shivpuri, 1983; Mathew, 1989). The greatest amount of ventilatory compromise is seen during the continuous phase of sucking. Some respiratory stabilisation occurs during the intermittent sucking phase of feeding. Even though breathing frequency and tidal volume remain low during sucking, periods of pause allow for almost complete recovery. However overall recovery depends on the number and length of pauses and how well the infant breathes during them (Mathew, 1989). Shivpuri (1983) showed that ventilation at the end of feeding was comparable to that in the control period prior to commencing feeding. He suggested that the decrease seen in  $TcPO_2$  during sucking was temporally related to the decrease in minute ventilation and that the increase in  $TcPCO_2$  during and at the end of feeding was consistent with a decrease in minute ventilation during feeding. It is generally considered that the ventilatory changes associated with feeding are due to the frequency of swallowing. In studies where milk flow is artificially adjusted, changes in the pattern of sucking and swallowing are seen (Al-Sayed, 1994; Mathew, 1989).

Al-Sayed (1994), in a study of 11 paired trials of 7 infants between 5 and 12 days old, showed that where there was low pressure and thus low passive milk flow, there was a sucking frequency of 0.45 sucks/sec. and a suck volume of 0.07 mls/suck. In addition swallow volume was 0.11 ml/swallow. However when the pressure was altered to give a high milk flow, sucking and swallowing frequency also altered to 0.88 sucks/sec. and 0.64 swallows/sec. Volume per suck and swallow also increased to



0.17 mls. and 0.23 mls. respectively. They concluded that the associated decrease in minute ventilation during the high pressure position was due to an increase in swallow frequency and decrease in respiratory frequency only as tidal volume did not change. They also saw no other effect on ventilation with the change in swallow volume.

### **2.2.2    *Breast feeding***

There appears to be debate as to which element of the sucking mechanism applies in breast feeding. Ardran (1958) describes the infant using suction to draw the nipple into the mouth and elongate it along the tongue groove. Milk is then expelled into the mouth with the aid of the 'let-down' reflex and positive pressure (compression of the teat/nipple). Negative pressure (suction) facilitates refilling of the sinuses and ducts (Lawrence, 1989). Smith (1988) however observed that milk is expelled into the mouth 30 msecs. after the maximum compression of the teat/nipple in conjunction with the creation of negative pressure. It would appear, through techniques used in the artificial extraction of breast milk, that an element of both mechanisms apply.

The organisation of breast feeding is distinctly different from that of either non nutritive sucking or bottle feeding. Bowen-Jones (1982) showed that in term infants sucking rates at the breast were similar to those bottle feeding but the pattern was different. They concluded that where there was a decrease in milk flow there was a high sucking rate, as reported in non nutritive sucking, and where there was a high milk flow there was a decrease in sucking rate. It has been suggested that prior to the let-down reflex sucking frequency is similar to that of non nutritive

sucking but after the reflex has occurred, when milk flow is high, the sucking rate decreases. In the latter half of feeding, sucking rates increased as the milk flow diminished (Woolridge, 1986). In a study looking at the effects of satiation or fatigue in feeding, a similar pattern was repeated on the second breast (Drewett, 1979).

Mathew (1989) compared the effects of breast and bottle feeding on 15 term infants within the first few days of life. They found that the pressure generated at the breast was significantly less than that with a teat. They also looked at the effect of feeding method on ventilation and showed that during breast feeding the inspiratory time was significantly reduced but there was no significant difference with expiratory time or respiratory frequency. They acknowledge that lactation was not established and this may have caused less swallowing to inhibit respiration. In terms of oxygenation they found that infants were less likely to desaturate or have bradycardia during breast feeding than during bottle feeding. This however may have been due to the limited milk flow.

The combination of low milk flow, self regulation and increased non nutritive sucking may assist the infant in maintaining stability and increasing weight gain. A postulated mechanism might be:

- a) Initial sucking prior 'to let down' reflex calms the infant and organises physiological and behavioural state in readiness for the milk.
- b) Feeding experience prior to establishment of maternal lactation allows the infant time to establish the suck, swallow, breathe mechanism with limited milk flow.

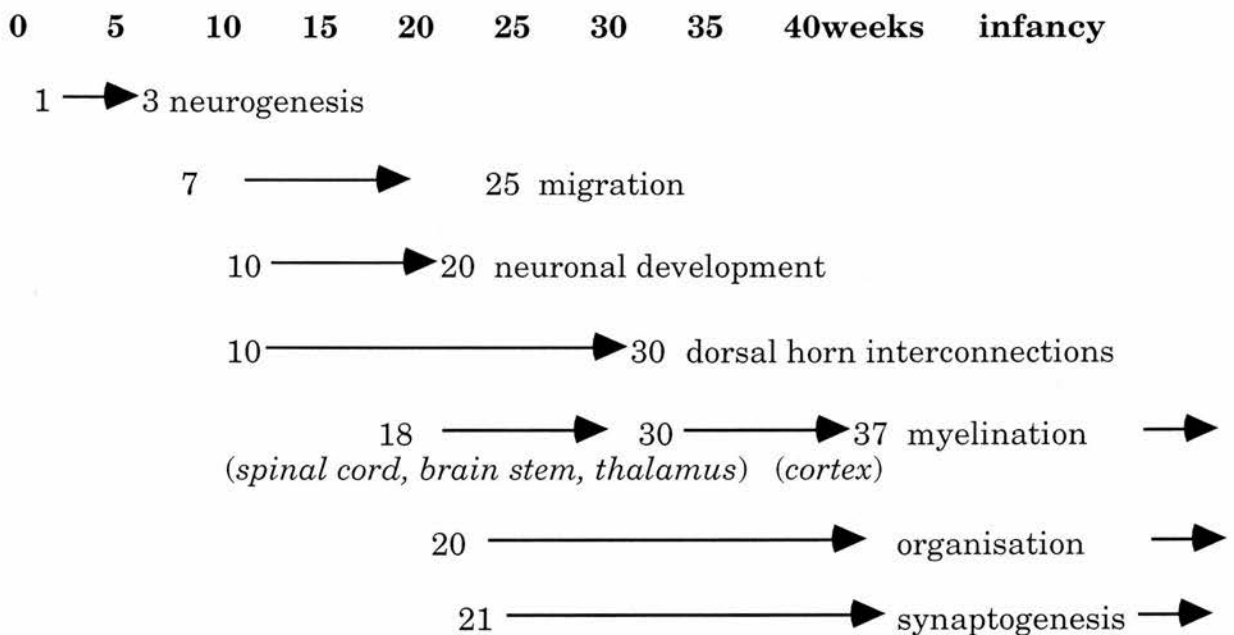
- c) The mainly non nutritive, comfort sucking which occurs after nutritive sucking in breast feeding may increase lingual lipase and gastric enzyme secretion thereby aiding milk absorption as well as stabilising behavioural and physiological state.

The literature presented illustrates the highly delicate and sensitive nature of oral feeding. However not all infants are born at term with the necessary skills for successful feeding. The preterm infant is potentially compromised in a number of ways. The very nature of being born prematurely increases the risk of the immature and vulnerable brain to experience insults which would otherwise not have occurred. These in turn may affect central nervous system development and subsequent functioning. Furthermore the infant anticipates physiological, motor and sensory support from the maternal host and is therefore subjected to a bombardment of stimuli for which he is unprepared. All of these factors may affect the development of oral feeding. The following section describes the influencing factors in the maturational development of feeding and the subsequent difficulties premature infants may encounter.

## 2.3 Influential factors in the maturational development of feeding

### 2.3.1 Development of the fetal brain

'Mechanisms of feeding' has demonstrated the multisystem nature of oral feeding. For each system to operate independently and yet collectively, requires precise functioning of the brain and central nervous system. However many obstacles are presented which may affect normal growth and development. Growth and development of the human brain begins during embryogenesis and is not complete until some time after birth (Spinelli, 1990; figure 2).



*Figure 2* Development of the central nervous system. Adapted with permission of Prof. N. McIntosh, Dept. of Child Life & Health, University of Edinburgh

Abnormalities of the brain and central nervous system development which arise during the first half of pregnancy are often unexpected resulting in little that the caregiver can do to prevent or minimise their effects. Therefore this period of development is described only briefly but it provides background to later functioning and is therefore included in the text.

The first phase of embryological development is the growth and development of nervous tissue. These cells originate from the embryonic ectodermal tissue and within three weeks of gestation form the neural plate and crest. Subsequently folding and groove formation occurs and the neural tube is formed. Lining the tube are primary neuroepithelial cells which give rise to neurones and glial cells. The majority of these neurones originate some distance away from their final functioning site. Although they are undifferentiated their destinies appear to be assigned (Gilles, 1983).

Most neurones of the brain stem and spinal cord are generated by 10 weeks gestation and those of the forebrain and cerebral hemispheres by 20 weeks gestation. The glial cells (non-neural support cells), being astrocytes and oligodendroglia, play an important structural and conductive role in the nervous system.

The differentiation and proliferation of neurones may occur before or after migration but their purpose is predetermined; therefore with migration to a specific area in the cortex, unique mapping of the brain surface occurs (Gilles, 1983). Migration proceeds along a course where the earliest formed cells inhabit the deepest cortical layers and the later

formed cells the more superficial layers. The radial glial cells of the forebrain are thought to be guide cells which aid the outward migration of neurones.

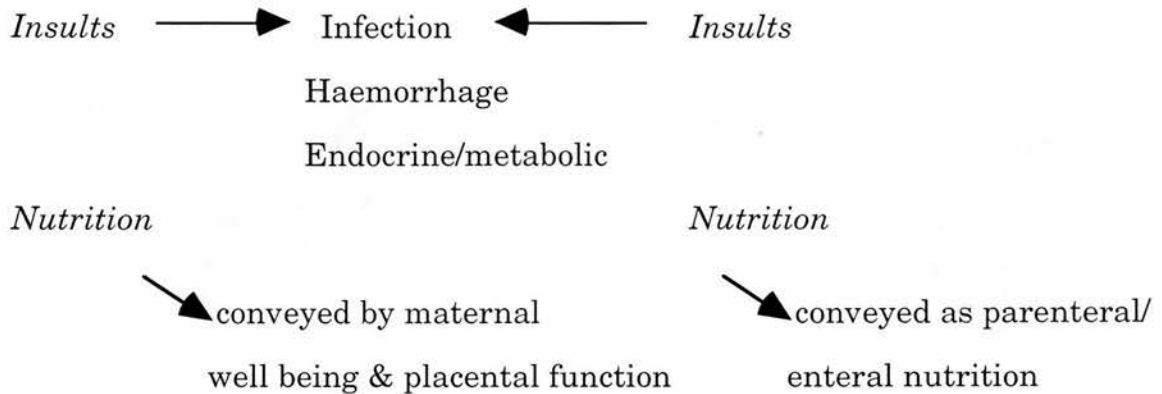
The influencing factors during this stage of brain development are those of parent genes, placental function and maternal health and behaviour (figure 3). Aberration in genetic information e.g. Trisomy 18, may be carried and transferred to the developing fetus causing incomplete or abnormal brain development. Placental function may be suboptimal due to raised blood pressure or abnormal embedding site. This may lead to poor delivery of nutrients and gaseous exchange. Fetal and newborn health may be compromised by poor maternal diet (Rush, 1993), by maternal infection e.g. cytomegalovirus, which may affect fetal brain development or by personal substance abuse e.g. alcohol/cocaine, which again may affect development (Saigel, 1982; McCalla, 1992). These influences may be minimised by screening, health promotion and education but their effects would continue to be seen whether infants were born prematurely or not.

*Intra-uterine*

*Genetic*

*Extra-uterine*

*Stimulation*



*Figure 3* Influencing factors on brain structuring

The second phase of development is that of growth and differentiation; it is during this phase that if born, fetuses have a chance of survival and therefore are particularly vulnerable to imbalances within their system functioning and brain development. Organisation and myelination of cells occur from about twenty weeks gestation and continue into infancy.

Volpe (1987) describes this stage as a process involving:

- attainment of functioning cortical neurones,
- enlargement of the cell with extension of axons and dendritic processes,
- differentiation of glial cells and myelination,
- synapse formation,
- excitatory and inhibitory synapse activity and
- cell death and selective elimination of neuronal processes.

Following migration the neurone undergoes a transformation. Dendrites and their spines evolve allowing each cell to connect with many others. These interconnections are essential for central nervous system (CNS) development and communication as they provide the major proportion of surface area for the development of synaptic connections and the balancing and integration of synapse activity. During the growth spurt of the cerebellum, between 30 and 32 weeks gestation, there is an increase in dendritic connections. Insults to the brain at this time may lead to altered motor development as seen in some premature infants (Bedi, 1988).

As the surface of the brain changes from a smooth to convoluted appearance, differentiation of function occurs. Between 26 and 28 weeks gestation there is prolific growth of the brain and a change in head shape. The germinal matrix, which gives rise to neurones and glial cells, is densely infiltrated by tiny blood vessels. With migration of neurones and glial cells, these blood vessels are left unsupported and up 34 weeks gestation are susceptible to haemorrhage (Volpe, 1987). Differentiation of glial cells allows for the myelination of axons so improving conductivity of electrical impulses.

Myelination has a temporal sequence which proceeds proximal to distal along an axon. In the peripheral nervous system it occurs in the motor and then sensory nerves from 20 weeks gestation. In contrast, in the CNS it occurs first in the sensory and then the motor networks. Myelination here occurs from 18 weeks gestation and is completed in the spinal cord, brain stem and thalamus by 30 weeks gestation and from thalamus to cortex by 37 weeks gestation. Myelination has an important role as an



insulator of individual fibres so increasing specificity and speed of connections as well as the number of connections (Sarnat, 1984). Complete myelination of many pathways is not complete until adulthood (Yakovler and Lecours, 1967). Moore (1988) suggests myelination of the CNS occurs prior to maturation of functional ability and therefore sensory systems begin to function before their structures have completely matured. As myelination is concerned with enhancing neural activity it is important when considering the sensory and motor involvement and regulation associated with oral feeding. Structural maturation processes may be influenced by function before complete maturity is achieved (Bradley, 1975). However the process of myelination may be interrupted by infection, dehydration or malnutrition and therefore the infant may be compromised before or after delivery (Bedi, 1988).

During development there is an excess production of neurones, as there are axons and synapses during the organisational stage. Whilst the exact reason for this excess is unknown, there is the suggestion that when the appropriate neural activity is achieved, selective elimination of excessive cells occurs (Cowan, 1984). If damage should occur to a neuronal process, these excess cells may be utilised to preserve function. Thus selective elimination may be considered a terminal mechanism of development.

With the increasing cortical activity of the last 12-14 weeks of gestation the fetus develops 'state' awareness. The uterine cavity provides regulated sensory input supporting the infant as he differentiates between sleep and waking (Avery and Glass, 1989).

### **2.3.2     *Extra-uterine influences on brain development***

As a sensitive uterine environment and well functioning placenta with regulating blood supply and nutrition are influential in early gestational development, so are they also later in development. The problem arises in the event of a premature birth where an immature organism attempts to proceed along the normal developmental path of a fetus.

It has been suggested in stage 2 that insults to the brain at various stages in development can cause damage. The influencing factors which may lead to these insults, in the extra-uterine environment, are indicated in figure 3. Nutritional support may be provided parenterally or enterally. There are many disadvantages to using parenteral nutrition and therefore enteral feeding with either breast or formula milk is preferred. Breast milk is considered the most appropriate because its combination of nutrients, anti-infective elements, hormones and growth factors offers the best in nutritional value for brain protection and development.

However breast milk is not an essential determinant for brain development but of greater concern is the influence external stimuli has on homeostasis and thus brain development. The normal developing fetus takes account of the required changes in homeostasis and with the aid of the placenta and uterine environment adjusts function according to need. However, when presented with this compensatory task without the additional maternal support, during a particularly sensitive period of brain growth, alteration in blood supply can lead to haemorrhage and hypoxia and frequently impairment and handicap (Dietch, 1993). The

cause of this is associated with immaturity of structure and function of the brain and other systems as well as the presence of overwhelming stimuli for which the infant is unprepared and is ill-equipped to regulate (Avery and Glass, 1989; Becker, 1991; Oehler, 1993).

It has been indicated in section 2.3.2 that brain development may be altered by nutrition, stimulation and/or insults; that these "conditions" may subsequently affect feeding ability because of the ensuing abnormalities. However in the absence of these "conditions", prematurity itself, may disadvantage the infant in attaining feeding skills.

### **2.3.3      *Prematurity***

Co-ordination of the mechanism of feeding is not reported to occur before 32-34 weeks post menstrual age although individual elements and non nutritive sucking occur well before this time (Braum & Palmer, 1986; Shaker, 1990).

The condition of prematurity disadvantages the infant in three ways:

- neuromuscular instability,
- physiological immaturity,
- negative experience and re-inforcement.

Bosma (1972) describes several structures which impact on the successfulness of oral feeding. The premature infant lacks what he considers the 'exoskeleton' of subcutaneous fat which supports oral and pharyngeal function. The buccal sucking pads of the cheeks are either

absent or diminished depending on post menstrual age (Morris, 1982). Poorly developed connective tissue and ligaments limit muscle tone of the tongue and mouth so allowing the mouth to gape open. The lack of closure combined with a small tongue promotes less positional stability. The freely moving tongue may rest in the back of the oral cavity or against the hard palate. This prevents the infant from being able to locate or expel milk from the teat/nipple. Weak muscle tone is also reflected in reduced sucking strength and endurance (Caesar, 1982).

Postural instability is thought to be a result of insufficient muscle and tone and the habitual extended positioning associated with intensive care (Barb, 1989). The lack of flexion reduces the stability of the tongue and causes excessive jaw movements. Bosma (1988) suggests that postural control of the head, neck and shoulders is essential to maintaining a clear airway. If there is excessive flexion or extension during feeding the airway will collapse with apnoea and bradycardia ensuing.

Adaptive and protective reflexes are essential to successful feeding. As described previously, they are present from an early gestational age. However synchronisation between them is not thought to occur before 34 weeks post menstrual age (Caeser, 1982; Hack, 1985; Brake, 1988) and therefore oral feeding is cautiously allowed before this time.

There are a limited number of studies describing the development of nutritive sucking in the premature infant. Medoff-Cooper (1989, 1991, 1993) has documented the development of bottle feeding in infants from 32 weeks gestation to 36 weeks gestation. In these studies a clear maturational process is seen. With increasing gestation the overall

number of sucks increase as do sucks/second and sucks/burst. In addition sucking pressure also increases and with this, individual sucking time decreases as does burst time. The author suggests that the increase in suck number and pressure with the reduction in suck time all reflect increasing organisation and feeding efficiency.

Bu'Lock (1990) describes the development as a progression towards the preferred coordination of equal frequency in sucking, swallowing and breathing. In this study the infants of 33-34 weeks gestation required up to 4 sucks to achieve a swallow, with sucking organised into bursts, interrupted by periods of pause with rapid breathing.

Meier and colleagues (1985 & 1987) describe the development of breast and bottle feeding in premature infants using a within-subject design. In the first of these studies 3 mother-infant pairs of 35 weeks gestation were video-taped for a total of 18 hours. Meier et al reported infants as initially having a fast sucking rate (similar to that in non nutritive sucking) and then a slower rate with integrated swallowing and "self regulated pauses". Synchronous with the change in sucking pattern is the comment by mothers of feeling the let-down reflex. When offered a bottle feed, the infants showed little variation in sucking pattern whereas during breast feeding infants had periods of both nutritive and non nutritive sucking. Overall breast feeding sessions were longer than bottle feeding sessions; burst time lengthened with pause time shortening only during bottle feeding. Pause time remained lengthy during breast feeding.

In the second study 5 mother infant pairs from 32 weeks gestation were monitored for 71 feeding sessions. A within subject design was used

comparing infant responses to both breast and bottle feeding. Here it was seen that a burst pause pattern developed from the first breast feed but with bottle feeding it took a further two weeks to occur. With increasing gestation and maturity, feeding became more organised during both breast and bottle feeding.

As previously discussed compromise in ventilation is seen in the term infant during nutritive sucking. How much more is an immature infant likely to be affected?

Shivpuri et al (1983) measured ventilation in response to swallowing in 23 infants between 34 and 38 weeks gestation. An initial period of continuous sucking was seen in all but 1 infant, followed by intermittent sucking and pausing. During continuous sucking there was a decrease in minute ventilation due to a reduction in tidal volume and respiratory frequency. However in the older infants some recovery in ventilation occurred during intermittent sucking. As tidal volume remained the same between groups of infants, the difference observed was that of respiratory frequency. As changes occurred in minute ventilation so too was there alteration in  $TcPO_2$  and  $TcPCO_2$  levels.

During continuous sucking  $TcPO_2$  fell in all infants but in the more mature ones, it recovered somewhat during intermittent sucking. However by the end of feeding  $TcPO_2$  in the mature infants was lower than in the immature infants. The authors suggest that the fall in  $TcPO_2$  with sucking is temporally related to the decrease in minute ventilation and is consistent with the observed increase in  $TcPCO_2$ . However no comment was made as to why the mature infants had a lower  $TcPO_2$  at



the end of feeding but it was considered that ventilation was comparable at the end of feeding to that in the control period.

The studies conducted by Meier and colleagues (1985 & 1987) offer an opportunity to examine differences in feeding ability between breast and bottle feeding in the same infants. This situation arose because of feeding practices of that time and parent locality. Infants of a certain weight were restricted from breast feeding and parents were usually resident some distance away from the nursery and were therefore unable to visit regularly.

In Meier's study of 1987, the physiological responses to breast and bottle feeding were remarkably different between the two feeding methods used. During the bottle feeding sessions there was significant decrease in TcPO<sub>2</sub> with some recovery towards baseline during pause periods. Frequent bradycardia was also seen. During breast feeding there were fluctuations in TcPO<sub>2</sub> but these were around the baseline and of no consequence to the infants. No bradycardia was observed.

It has been demonstrated by others that an increase in milk flow leads to an increase in swallow frequency and thus a reduction in respiration (Al-Sayed, 1994; Shivpuri, 1983). However in Meier's study (1987) even the smallest of infants were able to suckle post let down milk without distress. Meier suggests that infants may be able to regulate sucking pressure according to flow rate from an early age to "facilitate distress free feeding" (p.103).

In a study looking at the transition from bottle to breast feeding, the length of time of bottle feeding appeared to be related to the ease at which breast feeding was established (Meier, 1985). Infants who had had an occasional bottle feed in the previous 3 to 4 days had little difficulty in establishing breast feeding. However the infants who had exclusively bottle fed for a longer time had great difficulty in establishing breast feeding. These findings support the notion of teat/nipple confusion which is generally attributed to the difficulty of establishing breast feeding once infants have been offered a bottle (Neifert, 1995). No clear explanation accounts for the difficulty premature infants experience in changing from bottle to breast feeding, however some factors which support the 'confusion' argument are:

- a) difference between teat and nipple position within the mouth,
- b) variation in rate of milk flow and frequency of swallowing and
- c) difference in co-ordination of the suck, swallow, breathe mechanism.

This idea coupled with the view that practice and experience promotes the development of feeding skills has led some practitioners to examine other feeding methods.

Cup feeding, a method of feeding whereby infants initiate feeding by lapping milk from a small cup, has been demonstrated to provide positive oral feeding experiences whilst not compromising or confusing the infant (Lang, 1993; Jones, 1994). Personal observations suggest this mechanism to be similar to that described previously by Gryboski (1969) and Morris and Klein (1987) as the initial immature 'licking or lapping' method of sucking. It is currently practised in a number of neonatal units as one



method of supporting breast feeding. This method of feeding is not a substitute for breast feeding but only carried out when breast feeding is impossible because of maternal absence or where the infant is unable to suckle from the breast. Different techniques are implemented but one which appears to be successful encourages mothers to express the foremilk into a cup (Jones, 1994). This initiates the 'let-down' reflex and the infant is then encouraged to breast feed. Following the breast feed the infant is offered the cup. The amount of encouragement given and duration of feeding depends on the physiological and behavioural state of the infant. In most neonatal units this assessment is carried out on an individual caregiver basis using no particular assessment tool.

Severity of illness is often associated with gestational age and thus the younger the infant the more invasive and possibly distressing the support is. The premature infant with immature CNS is unable adequately to filter and buffer the diversity of environmental and caregiving sensory input he is confronted with. Therefore the infant easily becomes overly sensitive and stressed (Als, 1986). The inability to deal with sensory input may lead to a pattern of aversive responses especially in the facial and oral region where there are numerous tactile receptors. Negative association of repeated endotracheal intubation and fixation tape, oro/naso-pharyngeal suctioning and insertion of gastric tubes may be demonstrated in feeding aversion. Prolonged intensive care may deny infants comforting strategies of non nutritive or nutritive sucking and hand-to-mouth activities. These traumatic experiences, lacking in pleasurable oral stimulation, may lead to a pattern of oral defensiveness and give rise to difficulty in transition from gavage to oral feeding (Tuchmann, 1988; Anderson, 1984).

Differences in the acquisition of feeding skills may also be seen in infants of the same post menstrual age but different gestational age. Illingworth and Lister (1964) discuss a sensitive period for acquiring feeding skills. This period is the time the infant is most able and ready to learn a new skill given the appropriate stimuli. If however this sensitive period is lost, learning the skill at another time proves more difficult. This situation may apply where the infant has been denied nutritive sucking opportunities.

## **2.4      *Summary***

Successful and efficient oral feeding is dependent on co-ordination of respiration and heart rate, oral-motor control, flexed posture, stability and the presence of oral reflexes (Anderson, 1984, Updike, 1986, Daniels, 1988). "It is the culmination of specific neuromuscular, oral-motor and neuro-behavioural development" (Shaker, 1990).

It has been shown here that many premature infants are denied the opportunity to experience normal development and whilst they may exhibit signs of wanting to feed orally, their ability in and progress towards safe acquisition of feeding is often hampered. Als (1982) provides a theory on premature infant development which explains and confirms the literature and observations presented in this section. This theory is therefore adopted to support this research.

## **CHAPTER 3**

# Chapter 3

## Theoretical framework

### 3.1 *Introduction*

The arguments surrounding infant development rest on the theories of nature versus nurture, genetic versus environment, biology versus culture. These argue whether infant development is governed by genetic makeup, physiological maturation and neurological function or personal experience gathered from the physical and social environment. However Piontelli (1992) offers an interesting account of fetal behaviour within the uterine environment and its subsequent impact on the future development of the individual. In these studies motility, sensory function and behavioural states of 11 fetuses were described. Records were maintained throughout pregnancy and until the children were 4 years of age. It was clear from the descriptions that the "in-utero" fetus experienced many aspects of stimulation from early gestational life until birth and that there was continuity in aspects of behaviour from pre-through to postnatal life.

Merenstein and Gardner (1993) suggest development is an orderly process which occurs from the moment of conception and is continuous until adulthood. Both genetic make-up and intra-uterine environmental stimulation affects development and maturation of the central nervous system. Therefore the observations and beliefs of Pointelli (1992) and Merenstein and Gardner (1993) offer an extended view of the nature

nurture debate. The principles of development are dependent upon the concepts of continuous individual changes in growth, maturation and experience.

At birth, the well term infant has the physiological and sensory capabilities to communicate with the environment (D'Apolito, 1991; Brazelton, 1995). However over the last 15 years a dramatic shift in the viability of the newborn population has occurred (C.S.A 1981 & 1992); concurrently an increase in the understanding of and thus provision in care for premature infants have evolved. The preterm infant has neither the central nervous system integrity nor behavioural maturity to communicate in a meaningful or protective manner (Section 2.3.2). Consequently the traditional theories of development no longer apply to a population that completes its fetal maturation as a newborn in an abnormal environment.

### ***3.2 Theories on premature infant development***

Theories on the effects of the environment on premature infant development stem from three main premises:

1. deprivation of stimulation,
2. overloading of stimulation,
3. non-contingent provision in care/stimulation.

Historically preterm infants were viewed as being too fragile to cope with stimulation and therefore many neonatal units promoted "minimal handling" in their care policies. However the treatment being offered to these infants within the nursery environment prevented total isolation

and sensory deprivation. Subsequent reports on maternal deprivation suggested that some form of stimulation was required (Brimblecombe, 1978). Subsequently many intervention studies were conducted using a variety of stimuli (Field, 1984; Resnick , 1987; Bennett, 1987; White-Traut, 1993). However these reports vary in both subject and intervention manner. More recently it has become apparent that although the environment of the neonatal intensive care unit is stimulating, infants are able to communicate their competence/distress through physiological and behavioural indices and that a more appropriate manner of care based on contingent caregiving is optimal (Als, 1982).

Therefore the theory guiding this research is based on the empirical work of Brazelton (1973) with full term infants and the subsequent realisation that premature infants have a lower threshold for taking in, processing and responding to stimuli and thus are likely to become easily overwhelmed and disorganised (Als, 1983). It assumes that premature infants are unique in their developmental agenda; that physiological and behavioural development is neither that of a fetus nor a full term infant. Therefore the developmental capacities and abilities of the infant are viewed from the perspective of an individual attempting to rebalance himself in an environment for which he is unsuited and unprepared but which he is willing to engage according to his needs.

### ***3.3 Synactive theory of development***

#### ***3.3.1 Background***

Als states that “the preterm infant is not an inadequate or deficient full term organism but is a well equipped, competently adapted organism appropriately functioning at his stage and in his environment” (Als, 1986 pp.16).

From this standpoint the premature infant is expecting all of his needs, physical, developmental and sensory, to be met by the environment created by and within the maternal host. The infant is anticipating an existence as that of a fetus until 40 weeks gestation and when born, able to attract his mother’s attention and safely suckle. Suckling is the one developmental skill he has practised in utero and which is essential to his survival. However when born prematurely the infant is confronted by an abnormal and often hostile environment (Gorski, 1982). The birthing process initiates changes to his subsystem functioning for which he is unprepared. Physiological stability is most often achieved through technological support and nursing care, whilst his body which has been accustomed to flexion and buoyancy, is often unsupported to aid attachment and fixation of life giving and monitoring equipment. The environment becomes inappropriately stimulating by being bright and noisy with little change in pace or rhythm. The infant struggles to maintain stability, to organise his functioning and proceed along a path of development in a positive direction.

Impairment of development may arise in the premature infant from both direct or indirect insults. Birth trauma and/or events which lead to



fluctuations in cerebral blood flow will effect change. The infant may experience hypoxia and/or periventricular haemorrhage. However developmental impairment or delay may also occur in those infants who have not been subjected to such insults (Barb & Lemons, 1989). Als (1986) suggests that the premature infant's brain is overly sensitive to sensory information and unable to buffer or filter the quantity of inputs from lack of inhibitory controls. The atypical environment of the neonatal unit may cause stress overload and thus alter neural patterning (Black & Greenhough, 1986; Avery & Glass, 1989).

### ***3.3.2 Principles of development***

The Synactive Theory of Development, (Als, 1982 & 1983), draws on four principles of development:

1. Principle of species adaptedness - from ethology where the organism is species-specific at any stage of development and actively interacts with the environment to progress on the course of self actualisation,
2. Principle of continuous organism-environment interaction - from neuroembryology where the developmental process relies on continuous actualisation and refinement of the individual by feedback mechanisms so enhancing optimal development,
3. Principle of orthogenesis and syncresis - from organismic psychology where development arises from unspecific to specific differentiation, articulation and hierarchic integration and synchronisation of various subsystems,
4. Principle of dual antagonist integration - from motor system neurophysiology where the organism strives for smoothness of



integration by means of approach and avoidance behaviour (Als, 1989).

From these four principles comes the principle of synaction which proposes that the development and organisation of the human infant is specific to the species as well as the individual; that it is an active, ever changing process. Whilst some subsystems obtain and preserve equilibrium, others develop and become refined in their purpose and activity. At each stage in development the subsystems are functioning continuously and interactively, supporting and or adversely affecting each other when development is less than optimal; with maturity infants are able to seek or shut out stimulation according to need and thus development is both ordered and unique to each individual.

### ***3.3.3 Subsystem functioning***

The subsystems in question are:

- the autonomic system,
- the motor system,
- the state organisational system,
- the attention and interacting system and
- a self-regulatory balancing system.

The functioning of these systems (representing stress or control) may be observed by changes within their components. The autonomic system by the pattern of heart rate, respiration, infant colour, temperature control and gastrointestinal function. The motor system by posture, tone and quality of movement in response to both touch and change in position.

The organisational system by range, frequency, transition and clarity of sleep-wake states and attention and interactive system indicating the ability to alert, interact with and modify incoming sensory stimuli. Finally strategies utilised by the infant to remain balanced and relaxed or to return to such a state are seen in the functioning of the self-regulatory and balancing system.

Conceptualisation of this model focuses on four developmental stages. Als (1983) suggests that autonomic control and stability are central to the functioning of the other systems. With stabilisation and integration of this subsystem comes increasing motor activity leading to improved tone and posture. However infringement on physiological stability may still occur giving rise to compromising or defensive strategies. The third stage of development is the emergence and differentiation in levels of arousal from deep sleep to wakefulness and crying. The maturing infant is able to move swiftly between states to regulate incoming stimuli. Initially however there may be some disruption to motor control and possible physiological stability as the infant struggles to maintain an alert state. Finally the infant is able to maintain an alert state and participate in the activities shaping his developmental agenda.

### ***3.3.4 Neonatal individualised developmental care and assessment programme***

Als (1986) has utilised her theory in developing an assessment tool specifically for preterm infants; the Neonatal Individualised Developmental Care and Assessment Program, NIDCAP. This programme requires caregivers systematically to observe infant



responses to stimuli and provide a sensitive and caring approach which meets their needs and capabilities. There are few reports on studies utilising this total package of behaviourally sensitive care and in some there is possible bias in the selection of study and control groups (Als, 1986; Als, 1993). However all demonstrate significant outcome improvements with implementation of the programme. In relation to oral feeding, infants stabilise autonomic control before being offered stimuli which necessitate integrated motor function. With increasing gestational age state awareness develops and infants are provided with appropriate opportunities to develop and enhance oral feeding skills. Using this approach the studies report shorter time being taken for infants to progress from gastric to full breast/bottle feeding.

Textbooks suggest that oral feeding should not begin before 34 weeks post menstrual age but there is no real agreement amongst caregivers when it should begin nor the criteria for its progression (Biber, 1989; Behrman, 1992). Individual judgement is exercised in the decision making process. Als (1982) provides a model of development that focuses on the individual ability of each infant to manage the experiences of the world around him. She proposes that control and stability of physiological function, motor behaviour, sleep and waking and integration with the environment reflect central nervous system development and integrity and are thus indications of maturity. The limitation of this model is that it does not focus on any particular skill acquisition. However Wolf and Glass (1992) utilise the subsystems proposed by Als to create a framework of observation and evaluation to assess infant feeding ability.

### ***3.4 Model of effective feeding***

In an assessment and evaluation of oral feeding by Wolf and Glass (1992), four components are described which are subject to change but essential to effective feeding . These are:

- physiological control and stability,
- motor control and coordination,
- state organisation and
- caregiver attributes.

Physiological control and stability are predominant as coordinated breathing is part of successful oral feeding. Both activities, feeding and breathing, share a single conduit, the oropharynx, in their functioning. During swallowing when the milk bolus is directed towards the oesophagus there is inhibition of respiration. Persistent or prolonged airway closure can have a detrimental effect on heart rate and oxygen saturation (Mathew, 1988; Rosen, 1984; Guilleminault, 1984). Therefore infants must have control of autonomic function to regulate and integrate breathing with swallowing.

Motor control and coordination is necessary for many reasons. The infant must be able to elicit milk from the nipple/teat, propel it through the oropharynx, close and open the airway efficiently and finally initiate oesophageal peristalsis. These actions involve voluntary and involuntary control requiring effective muscular action and neural maturity. Bosma (1972) describes several structures involving facial and oral musculature which are necessary for positional stability and organised function to support successful feeding. In addition, neural maturity is required to

initiate action of protective reflexes and promote rhythmical coordination of sucking, swallowing and breathing.

State organisation is also essential as the infant needs to be sufficiently alert to attract his caregivers attention. Having achieved this he must remain in a state which allows sufficient suckling to meet nutritional requirements and support lactation. It is only with increasing gestation and age that changes in state organisation occur (Parmelee & Stern, 1972).

Finally caregiver participation in feeding is important. Caregivers must recognise the cues infants display for feeding readiness and ability and thus act upon them in an appropriate manner.

### **3.5 *Summary***

This study combines the theory of synaction and the model of effective feeding to support breast feeding organisation in infants admitted to the neonatal unit. The implication being that as infants mature and experience oral feeding there is greater stability in physiological function, increased organisation of feeding with rhythm and burst-pause definition and more consistent waking with active participation.

## **CHAPTER 4**

# Chapter 4

## Methods

### *4.1 Introduction*

The literature review in Chapter 2 discusses the factors which influence feeding development and organisation. As has been seen in the review, feeding is a skill derived from the integration of physiological regulation and stability, motor control and coordination and behavioural state organisation. However much of the previous research has been conducted only on bottle feeding infants and this may be because of:

- 1) the physical difficulty in measuring breast feeding activity in infants,
- 2) the common belief that infants should demonstrate successful bottle feeding skills before attempting breast feeding,
- 3) the difficulty some mothers experience in sustaining lactation before their infant is able to suckle from the breast,
- 4) the publicity/social culture attached to feeding infants by artificial means making bottle feeding the predominant feeding method.

As a result many assumptions and hence feeding guidelines are made about breast feeding infants from the data gathered from bottle feeding studies. The assumptions focus on the organisation and function of feeding. Textbooks frequently state that safe and efficient feeding does not occur before 34 weeks gestational age (Biber, 1989; Behrman, 1992)



and although no reference could be found, it is presumed that because breast feeding infants have to grasp onto and hold the nipple within their mouths, breast feeding is a more difficult activity to achieve than bottle feeding.

The basis for this belief may stem from caregivers' lack of experience in enabling successful breast feeding in premature infants at a time when specialised neonatal care was emerging. Nutritional value of feeding was also seen to be more important than the experience of breast feeding with infants receiving prescribed volumes at specified times. In addition in the past, parents were not encouraged to participate in their infant's care and thus were less likely to visit frequently and be available for breast feeding as determined by the infant's cues.

As a result infants traditionally do not begin breast feeding until around 34 weeks gestational age when bottle feeding may already have been established. Therefore the purpose of this study was to gather data on the organisation of breast feeding skills in infants admitted to a neonatal unit.

## **4.2 Aims**

The primary aim of the study was to describe the pattern of sucking, breathing and swallowing during breast feeding in infants admitted to a neonatal unit and the effect this feeding method has on physiological status.



### **4.3 Questions**

1. What are the patterns of sucking, swallowing and breathing in breast feeding premature infants?

(The assumption is that breast feeding is more complex than bottle feeding and coordination does not occur until approximately 34 weeks post menstrual age).

2. What is the effect of breast feeding on heart rate, respiration and oxygen saturation?

(The assumption is that breast feeding is stressful for the infant and thus increases the 'work' of feeding).

### **4.4 Methodology**

Undoubtedly breast feeding is the most beneficial feeding method for newborn infants and is therefore strongly promoted by health professionals (Williams, 1994). However caregivers are required to practise evidence/research based care (UKCC, 1992) and therefore information, advice and help offered by caregivers in support of breast feeding should be founded on a body of knowledge which has been accumulated and interpreted in a systematic way.

The design selection in any study is influenced by the aims and research questions of the study. However all designs are imperfect and have limitations but the role of the researcher is to select the design and approach which “best fits” the activities or variables of interest (Cormack, 1991).

Data may be generated using two broad methodologies:

1. that which generates qualitative data and
2. that which generates quantitative data

Studies which generate qualitative data generally use non experimental designs whereas studies which generate quantitative data may use either experimental or non experimental designs. Thus the approaches used within designs are not mutually exclusive (Field & Morse, 1985). The data collection method is influenced by the nature of information which is being sought and the type of analysis anticipated (Cormack, 1991).

#### ***4.4.1 Qualitative methodologies***

Qualitative methodologies have been associated with the systematic collection of data which gives meaning to human beliefs and values, life events and experiences (Leininger, 1985). The approaches used to collect this type of data include:

phenomenology- an approach which gives understanding to the essence of a phenomenon (Hallett, 1995).

ethnography- an approach which observes activities of everyday life in order to understand the beliefs and patterns of behaviour of people within their own environment (Baillie, 1995).

grounded theory- an approach which generates theory that explains the actions based in the reality of topic understanding (Benton, 1991).

All of these approaches have been used in breast feeding studies. They address the complex social and psychological issues of breast feeding function and activity. However the data generated cannot be generalised to the population as a whole but can assist caregivers in their understanding and provision of sensitive care to individuals and or groups of women within their cultural context. Clearly these approaches are inappropriate in studies where the experience of breast feeding is being sought from the perspective of the infant. However in clinical practice many caregivers inadvertently utilise a qualitative approach in assessing feeding ability and developing a plan of care by enquiring from mothers how they felt a particular feed progressed. Mothers often reflect on the feeding experience and explain it using similes and metaphors; e.g.

*“you could hear him swallowing the milk like water going down a drain”.*

*“I knew he was hungry because he was hoovering the sheets”.*

This gives caregivers information about a particular feed but not about the course of feeding development in preterm infants.

#### **4.4.2 Quantitative methodologies**

In order to predict or describe what happens as a general rule in a particular group of subjects, researchers have utilised methodologies which generate quantitative data. These designs are based on ‘traditional’ research methods; the key characteristics being objectivity, measurement and control (Polit & Hungler, 1991). Polit and Hungler

(1991) describe two interventionist designs: experimental and non experimental.

#### **4.4.2.1      *Experimental research***

True experimental research is generally classified as scientific enquiry; it is conducted under carefully controlled conditions where manipulation, control and randomisation of subjects and variables are essential to the design. Experimental studies test hypotheses for cause and effect relationships between manipulated variables. Because of restrictions imposed on the design, a strong level of prediction and thus confidence can be inferred from the established relationships. However the very strengths of true experimentation make it a design which is not appropriate for all issues of enquiry.

Not all interventionist research is amenable to true experimentation because of ethical or practical considerations and therefore a quasi experimental design may be adopted. Quasi experimental research is similar to true experimental research in so much as there is manipulation of the independent variable. However there may be lack of randomisation or a control group. This does not imply that this design is any less robust but it may be a more appropriate way to address the aims and questions of the study and the subjects under investigation.

In respect of infant feeding the choice of feeding method is a very personal and individual decision involving different levels of commitment from parents. The choice requires to be made before or within a few days of birth. Researchers have subsequently designed studies which answer

their questions but do not compromise parent choice. As such true experimental research has not been conducted within the area of infant feeding. However researchers have used quasi experimental designs where the independent variable (feeding method) has been manipulated once parents have made their choice on preferred feeding method (Meier, 1987; Mathew , 1989; Blaymore Bier, 1993).

Meier (1987) looked at the differences in outcome variables associated with the early introduction of breast and bottle feeding in premature infants. Infants whose mothers had already decided to breast feed were recruited. The researchers used a within-subject, repeat measures design to describe and summarise the differences between breast and bottle feeding activities. The feeding method was manipulated but there was no randomisation and infants acted as their own controls. This study demonstrated that infants could safely manage the experience of breast feeding approximately two weeks earlier than bottle feeding. A similar within-subject design was used by Mathew (1989) when determining whether milk composition and flow rate were the primary determinants in altering breathing pattern during breast and bottle feeding. They indicated that milk flow was more important in altering breathing pattern than milk composition. Again Blaymore Bier (1993) used a within-subject design to assess the clinical effects of breast and bottle feeding on low birth weight infants. Although infants in this study appeared to be less clinically stressed during breast feeding than bottle feeding they received many more bottle feeds in-between study measurements. In addition the weight difference pre- and post- feed indicated that during breast feeding infants consumed less milk than during bottle feeding. This was not unexpected but in association with



the large number of bottle feeds infants received and the time limits attached to the breast feeding sessions it may be argued that breast feeding was not necessarily optimally performed by the infant. Also half of the mothers discontinued breast feeding within one month of discharge citing poor milk supply as the reason. This is frequently associated with a poor sucking technique.

The within-subject nature of data collection used in these studies strengthens the design as there is no sampling variation and the extraneous variables are the same for each feeding method. In addition it reduces the number of subjects to be recruited and in the breast feeding preterm population this is an advantage (Presly, 1991). However there is evidence that the early introduction of bottles to infants whose parents wish primarily to breast feed may preclude successful breast feeding in those infants and in mothers who have a predisposition to experience difficulty in breast feeding (Neifert, 1996). Therefore in these studies the differences seen between breast and bottle feeding may be a result of one feeding method (or mechanism) influencing the other and not the feeding method itself.

With respect to Meier's and Blaymore Bier's studies, breast feeding sessions were determined by maternal visiting time and frequency. Thus there was no consistency in the timing of breast feeding data collection and therefore subjects could not be considered as similar in terms of maturation for each feeding method. In Mathew's study the feeding sessions were consecutively carried out on term infants with the feeding order being randomly selected. However it may be argued that in feeding studies where comparisons are being drawn, any time difference between

data collections inherently effects a change in the state of the infant and therefore possibly feeding behaviour. Also in breast feeding studies where milk supply is dependent on maternal lactation the results of data collected in the first few days post partum may be principally affected by lactation and not feeding method. This was acknowledged by Mathew as a possible influencing factor when he reported his study results.

#### ***4.4.2.2 Non experimental research***

Quantitative data may also be generated using non interventionist designs. Polit and Hungler (1991) describe two broad classes of non-experimental research. The first is descriptive research where studies do not focus on relationships between variables but rather describe the situation as it occurs naturally. No causality or inference is intended. The second is correlational research which looks for associations between variables. The pupose of this design is essentially the same as for experimental research; however in correlational studies causality cannot be inferred because of the lack of manipulation, control and randomisation.

Therefore non-experimental research is associated with studies where:

- 1) the independent variable has already occurred in the natural course of events and therefore cannot be manipulated,
- 2) where it is unethical to manipulate the independent variable because of potential harm to the individual,
- 3) for practical constraints where there may be concerns about subject safety or time and
- 4) also financial and convenience limitations.

By not being able to manipulate the independent variable there is an inability to randomise subjects into study and control groups and therefore there may be a tendency for self selection thus increasing the possibility of bias and erroneous interpretation of the results. Therefore the researcher needs to be precise in determining criteria for subject inclusion, consistent within their constraints in subject recruitment.

Although non-experimental research is limited in its robustness and application to infer causality, it is appropriate in studies where the intent is to describe a situation as it naturally occurs or to understand a relationship amongst phenomena as they naturally occur. It is therefore a research design based on reality and appropriate for many humanistic issues of interest.

Examples of non-experimental breast feeding research are studies conducted with well term infants by Bowen-Jones (1982), Weber (1986), Smith (1985), Lau (1989) and Young (1996). In these studies milk flow, organisation and pattern of sucking are described. Bowen-Jones (1982), Lau (1989) and Young (1996) use film to capture sucking rates on only breast feeding babies. Weber (1986) and Smith (1985) use ultasonography to describe the organisation of sucking and swallowing in both breast and bottle feeding babies.

In the studies using film, the number of participating pairs (mother-infant) were small and they were all from convenience samples. The results therefore reflect individual feeding accomplishment and a population trend in the variables considered; but with breast feeding



being such a personal activity it is more acceptable to recruit mothers who are willing and happy to be filmed. In Lau's study (1989) the twin infants were those of one of the investigators: thus by using a single mother and with twins much of the variability and potential bias associated with convenience sampling is reduced; in Bowen-Jones' paper (1982) the three studies reported on used separate mother infant pairs in all but the third study where differences within a mother-infant pair were reported on.

Estimation of milk flow was carried out using two methods. Bowen-Jones (1982) used test weighing every 3 minutes and correlated the results with sucking pattern to estimate milk flow during a feed. Lau (1989) used 5 and 10 minute test weighing intervals and correlated the difference with swallow activity showing that weight gain was associated with swallow frequency. The disadvantage of this method is the potential for disrupting the feeding rhythm and thus not reflect the normal feeding pattern. This was acknowledged by the authors but they did not feel it was of great significance. The greatest advantage of filming is that it is non-invasive to the infant and thus sucking activity may be accurately measured although it may be intrusive to the mother.

The ultrasound studies of Weber (1986) and Smith (1985) describe the events that occur within the baby's mouth during feeding. Again convenience samples were selected and infants were studied between days 2 and 6 in Weber's study and 2 and 4 months in Smith's study. Both breast and bottle feeding babies were selected and differences in feeding organisation between the two groups were described. The descriptive observations reflected the performance of the individual infants but

because of their similarity gave indications of population feeding organisation. However in Weber's study there was a clear problem in the breast feeding babies in so much as it was difficult to place the scan head in the correct position. However once placed correctly a large number of feeding sequences from each feed could be obtained for analysis and this negated the initial difficulty.

## **4.5 *Decisions governing this study***

### **4.5.1 *Design***

“Failure of existing rules is the prelude to the search for new ones”

(Kuhn, 1970, p 68).

A literature search found no substantial work which describes breast feeding in preterm infants. Therefore having decided from the literature and personal experience of the assumptions made regarding breast feeding in the neonatal unit, the purpose of the study was to describe breast feeding development in premature infants of differing post menstrual ages. Because of the moral and ethical issues surrounding infant health and parental choice of feeding method, it would be improper for a researcher to attempt to influence parents to participate in a study where there were manipulation, control and randomisation, the hallmarks of experimental designs (Polit & Hungler, 1991), of their infant into one feeding method or another.

A quasi experimental design similar to those outlined previously was considered but because of the current belief that sucking mechanisms are

different between the two feeding methods, it was deemed to be inappropriate. The principal reason is that by not introducing bottles to breast feeding infants no confusion in feeding mechanism could arise and therefore would be unlikely to reduce the successfulness of breast feeding or influence the research findings. Therefore unlike some other researchers, no attempt was made at comparing breast and bottle feeding outcomes in the same infant. This might be considered a weakness because no difference or advantage can be ascribed to one feeding method over another with increasing post menstrual age.

Therefore with respect to the current study, having decided on a non-experimental design, the lack of data on breast feeding development and organisation and the aims of the study suggested that a 'descriptive correlational' design was the most suitable. By using this design the focus was on describing the situation as it was. No attempt was made to establish or infer causality in the findings but rather to describe and explore the relationships between the variables at different post menstrual ages and determine whether the findings were consistent with the theoretical framework (LoBiondo-Wood & Haber, 1994). However the purpose of the study was not only to increase knowledge and understanding but also to support or challenge present practice and thereby influence the provision of care (Downs, 1979). Therefore this research had both a theoretical and practical basis.

Having decided on the design, there remained two considerations in the approach and method of data collection:

1. the type of data to be gathered and
2. how the data may influence the provision of care.

The type of data measured represented biophysical information relating to feeding development and organisation. Numerical data lends itself to quantitative analysis (Carter, 1991) and because of their objectivity, precision and sensitivity provide information on the measures required thus strengthening the results. However inclusion of any equipment to measure the activity of feeding may affect the outcome. Pressure sensitive catheters or pads may affect how the infant latches onto the breast and subsequently suckles, thus influencing the measurement in question. In addition, the presence of equipment and/or keenness or anxiety as experienced by mothers in participating cannot be ruled out. Infants may recognise subtle changes in their mothers which may alter their performance and have a secondary effect on the measurements obtained.

The instruments used to measure the variables associated with feeding development have included:

1. suckometers - to measure sucking events and pressures,
2. ultrasound - to measure sucking and swallowing events,
3. microphones - to measure swallow sounds,
4. electrocardiogram - to measure heart rate,
5. nasal thermister/anemometer and pneumotachograph - to measure air flow and inspiratory and expiratory phases of the respiratory cycle,
6. respiration bands - to measure chest and abdominal respiration,

7. pulse oximetry - to measure oxygen saturation,  
transcutaneous O<sub>2</sub> and CO<sub>2</sub> monitoring - to measure non-  
invasively blood gases and
8. videotaping - to measure events and behaviours.

The breast feeding studies conducted by Drewett (1979), Meier (1985 & 1987), Mathew (1989) and Blaymore Beir (1993) have used a combination of suckometers, ultrasound, electrocardiogram, respitrace bands, pulse oximetry, transcutaneous monitoring and videotaping. Each have looked at different components and aspects of nutritive feeding.

In reviewing these techniques advantages and disadvantages are seen. Pressure monitoring gives both event rate and rhythm as well as sucking pressures. It involves taping a fine catheter to the mother's breast. The distal end of the catheter is then attached to a pressure transducer and recorder. There are mixed reports on the effects of this technique. Drewett (1979) suggests it may produce disturbing tactile stimulation and refers to Gunther's (1945) findings of causing air leaks between lips and breast and also disturbing sucking. A more recent study, Mathew (1989) used a similar technique and found it caused no problems with breast feeding.

Ultrasound, which has no known harmful effects, has been used for imaging feeding co-ordination by both Smith (1985) and Weber (1986). However this method is costly with the level of training and expertise required for using the equipment and interpreting the results making it prohibitive.

Standard electrocardiogram (ECG) leads have been used by Meier (1987) and Mathew (1989) to measure heart rate. This involves placing three electrodes onto an infant's chest. The advantages of the ECG are accuracy in measurement with no loss of contact and the ability to record respiration by impedance. The disadvantage is in the subsequent removal of sticky-backed electrodes.

Pulse oximetry has been used in a number of studies to record both oxygen level and heart rate by a single wrap-around probe. The probe may easily be fixed to either the hand or foot by a small strip of non-adhesive tape and does not require frequent calibration. It is however subject to loss of contact if the infant is active.

Respiratory pattern can be monitored using two methods. A nasal thermister or anemometer placed beneath the nose records inspiratory and expiratory airflow but does not record tidal volume. It does not appear to affect feeding ability during bottle feeding, but cannot be used during breast feeding because of the close proximity of infant's nose and maternal breast (Mathew, 1989). The second method uses pressure sensitive pads, placed on the chest or abdomen (respiband). They are fixed over the infant's clothing using non-adhesive bands and do not appear to cause any disturbance (Ross, 1994). Synchronisation of breathing between these pads and the thermister shows good reliability.

Finally, videotaping has been used by Drewett (1979), Meier (1985), Lau (1989) and Young (1996) as a non invasive monitoring technique to highlight sucking, swallowing and behavioural events. This enables researchers to comment retrospectively on behaviour. It may however be

intrusive to some mothers, causing them to alter their behaviour. The technique is therefore carried out several times before being used in the research.

#### **4.5.2     *Pilot studies***

In the present study a number of techniques were attempted to obtain the data required to answer the questions. As breast feeding is a very personal activity the researcher attempted to be as non-invasive as possible. The use of video was first attempted. Although some mothers were initially self-conscious this was overcome by reassurance from the researcher that no other person would view the recordings. The method was also successful in capturing the suck swallow sequence. However no physiological data of heart rate, respiration and oxygen level could be collected without use of additional equipment and storage method. Using a stand-alone multi-channel monitor with a specific computer programme, MARY(1,2), which records and stores physiological data was also attempted (Cunningham, 1992). This was successful in capturing all the elements of feeding; however the equipment was not dedicated to the current research and was in frequent use by clinicians and other researchers. As a result it was not available as required. Therefore a technique had to be devised which captured the data reliably and was not cost prohibitive.

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1. Mary Neonatal Monitoring. Meadowbank Medical Systems Ltd., Loughborough.
  2. Mary is the name adopted from the clerk who initially used the system.



Pressure sensitive pads have been used reliably to measure breathing. With movement of the chest or abdomen a pressure change is detected in the sensor (Ross, 1994). It was decided to test whether this could be used to measure sucking occurrence. The sensor was placed and held in position just behind the anterior aspect of the chin. As the infant lowered the jaw to suck, the sensor detected movement and registered a suck [figure 1, appendix].

As many of the infants had indwelling naso-gastric tubes an external method of measuring swallowing was thought to be the least disruptive method. Using a microphone has proved successful in bottle feeding studies (Selley, 1992). However in this study the limited space between the infant's jaw, neck and maternal breast made using the microphone difficult. Although it was small in size, it was subject to interference by movement and the signal was unclear.

Therefore the use of a stethoscope with the researcher listening for swallowing and then triggering a mark on the computer programme when it occurred was considered the best method (Vice, 1990). The swallow frequency was reliably recorded but because of the time lag between the actual swallow occurring and the researcher indicating a swallow, no analysis could be made as to its precise occurrence in the breathing cycle.

The physiological data of this study included heart rate and oxygen saturation measured by pulse oximetry using the infant's foot for sensor placement. By placing a sock over the infant's foot prior to dressing him in a babygro ensured there was minimal loss of contact or artifact from



the pulse oximeter sensor. Breathing was measured by a pressure sensitive pad placed over the infant's clothing and positioned centrally, approximately one centimeter above the umbilicus.

The data from these individual pieces of equipment were collected via the Densa Pneumogram and stored in a dedicated computer programme, SNAPSHOT (1). Sampling rate was 20 per second at 20 KHZ.

As has been shown, physiological functioning may be affected by behavioural state and therefore data relating to this were also collected. In addition a number of feeding behaviours have been implicated in success of feeding, and therefore account was made in this study as to the infant's behaviour prior to and after feeding.

Two methods of assessing behaviour were used. The first one considered behaviours of feeding readiness and ability as described by Matthew (1988). In studies with term infants she found that if infants scored between 10 and 12 it indicated a vigorous feeding pattern (group 1), 7 to 9 moderately effective pattern (group 2) and 0 to 6 being those who could not be roused or who were disorganised in feeding (group 3). This scoring system consisted of 4 key components - readiness to feed or arousability, rooting, fixing and sucking pattern. Two other items, infants' sleep/wake state prior to feeding and maternal satisfaction with feeding were also scored but not as part of the infant feeding scale. For the current study Matthew's (1988) Infant Breast feeding Assessment Tool was adapted to include activities associated with oral feeding and a maternal score on self perception of feeding success.

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1. SNAPSHOT. Densa Ltd., 31 Manor Park, Flint, Clwyd.

Therefore the scoring system used in the current study consisted of 7 components:

*Wakefulness.*

2= alert; 1= drowsy; 0= asleep.

*Hand to mouth activity*

2= purposeful; 1= occasional; 0= none at all.

*Readiness to feed or arousability.*

3= feeds readily without effort; 2= needs mild stimulation; 1= needs vigorous stimulation; 0= could not be roused.

*Rooting.*

3= roots effectively; 2= needs prompting to root; 1= roots poorly despite prompting; 0= did not try to root.

*Fixing.*

3= feeds at once; 2= takes 3-10 minutes to latch on; 1= takes over 10 minutes to latch on; 0= did not feed.

*Sucking pattern.*

3= sucked well; 2= sucked on and off; 1= sucked poorly; 0= did not suck.

*Maternal perception of feeding ability from fullness of breast post feed*

2= fed well; 1= fed moderately well; 0= fed poorly

The second assessment considered the infant's level of arousal prior to and after feeding. Gill (1988) described feeding organisation as being optimal when the infant was in a quiet alert state. The behavioural state scale which was used in this study in conjunction with monitoring of biophysical parameters was that developed by Gill and colleagues (1988). The Anderson Behavioural State Scale (ABSS) is a twelve category scale designed to assess preterm infant behaviour [table 2, appendix]. It has been adapted from that described by Parmelee and Stern (1972) and ranges from very quiet sleep to hard crying. Categories 1 to 5 are termed

sleep states; 6 and 7 are inactive awake states and 8 to 12 active or restless states. After a period of two minutes from the last intervention the infant is observed and assessed for each 30 second interval of the observation period. The highest numbered behavioural state is recorded except when the optimal number, 6 - alert inactive, occurs. This supersedes any other state which occurs within the 30 second time interval. Content validity of this scale has been established and documented (McCain, 1992).

There are disadvantages in using behavioural assessments. Assessment is made from the viewpoint of the assessor. There is therefore a degree of subjectivity as the assessor attempts to recognise and interpret subtle cues and behavioural responses of the infant. However the use of a structured assessment scale and only one assessor who has undergone training in infant behaviour reduces the incidence of possible bias and perceptual error.

In the current work, pilot studies were conducted on six mother-infant pairs (term infants). With these subjects the researcher became proficient in applying the equipment, recognising swallow sounds and observing behavioural state. In addition, two other recordings were made with infants whilst bottle feeding. In these subjects the rater reliability was tested as the researcher's recordings of swallow were simultaneously collected with those of a microphone placed along the lateral aspect of the infant's neck. The pressure pad monitoring sucking was also assessed for reliability as it was used in conjunction with intra-oral pressure monitoring during the two bottle feeds. This was necessary to ensure

that the data collected reflected the occurring activity. [Results of pilot study, Table 1 appendix].

It was hoped that the findings of the study would contribute practically to nursing assessment and care. However to do this they had to be accurate representations of the experiences of clinical caregivers. To support this the study was conducted within the setting of the neonatal unit.

#### **4.5.3      *The setting***

The study was carried out in a single large level 3 centre for neonatal intensive care with intensive care and high dependency/special care nurseries being separated. Approximately 500 infants were admitted to the unit during the data collection period. All data were collected in the naturalistic setting of the low dependency areas.

The "naturalistic" setting of the low dependency area was chosen for a number of reasons. Firstly, practicality; many infants were being cared for in incubators and attached to monitoring equipment recording heart rate and oxygen level. Incubators were used for small infants to regulate their temperature and aid caregiver observation. The environmental temperature of the nursery was only slightly lower than that of the incubators so that when infants were taken out they did not have to be overly dressed or swaddled to maintain their temperature. The quiet side room outwith the nursery area where infants could have been taken for the data collection was much cooler than the nursery and although infants are able to maintain the temperature during breast feeding, the use of the side room was considered unsuitable for the small infants. In

addition, caregivers within the nursery had to observe the infant's responses/reactions to feeding and therefore the feeding activity and monitoring equipment had to be easily and readily observable.

Secondly uniformity; the larger infants who were cared for in cots and not receiving any monitoring could have been observed and recorded in the side room. However this would have introduced a pronounced difference in environmental stimuli between the fragile and the more robust infants and thus potentially alter the results. By collecting the data within the nursery it may be argued that the data were unreliable as feeding organisation may be unduly influenced by the setting. The most significant environmental influences were thought to be from fluorescent/bright lighting, loud and/or persistent noises and multiple caregivers (See Literature Review). None of these were able to be manipulated directly by the researcher. However by collecting the data from the one centre, all infants had experienced consistent medical and nursing interventions and care. The use of only one data collector, place of data collection and timing of data collection were considered to be regulating factors and therefore introduced some degree of uniformity and control.

Thirdly influencing practice; the questions of the study were derived from a perceived mismatch between theory and practice and therefore, for the results to have any impact on clinical practice, they should be obtained from data collected in the clinical setting. This reduces the criticism of artificiality and strengthens the utility aspect of the study.

#### **4.5.4      *The sample***

The research aimed to be informative about groups of infants of varying gestational age at birth and post menstrual age at time of study. The sample selected attempted to be as representative as possible to ensure that the effects of extraneous variables were minimal. However because the study design did not support randomisation, infants were selected from a convenience sample. This however increased the likelihood of bias and therefore inclusion into the study was determined by agreed criteria. The use of criteria attempted to make the subjects as similar as possible and therefore representative of low risk preterm infants (Cormack, 1991).

All infants admitted to the neonatal unit whose mothers had expressed a wish to breast feed within 3 days of their infant's admission to the neonatal unit were considered. Those infants who had a congenital abnormality of the upper airway, mouth or gastro-intestinal tract were excluded as were those infants with a diagnosis of birth asphyxia, bronchopulmonary dysplasia, intracranial abnormalities or grade 3 or 4 periventricular/intraventricular haemorrhages. Therefore the findings obtained may only be generalised to the defined groups and not to the population as a whole. Implementing such wide exclusion criteria supports the concept that only well low-risk premature infants were recruited.

#### **4.5.5      *Access***

All parents were approached for written consent to participate only if their infant(s) fulfilled the inclusion criteria. It was only when the infant

was admitted or transferred into the low dependency nursery that observation/monitoring was begun. Recruitment also depended on the workload of the researcher and therefore a convenience sample was selected. The time frame for recruitment was one year. Ethical approval was given by both the Hospital Ethics of Research Committee and the Health Board Ethics Committee. The monitoring data was stored within the computer programme SNAPSHOT. Summary data of biophysical measurements, behavioural observations and demographic information were transcribed into a spreadsheet. Storage of all the data was by computer.

#### **4.5.6      *Demographic information***

A detailed record from the infant's case notes was made regarding individual mother's demographic details and pregnancy and labour history. Information of each infant's birth and subsequent life events were also documented; a record pertaining to gender, weight, gestation and Apgar score was made.

#### **4.5.7      *Recordings***

Commencement of oral feeds was decided upon by caregivers in accordance with unit guidelines and normal practice. No monitoring was carried out before day five following birth to enable establishment of lactation. It was intended that each infant was observed/monitored weekly until full oral feeding was established or parents changed their feeding method, withdrew from the study or were transferred to another hospital, this usually being the referring hospital.



For those infants on scheduled feeds the monitoring equipment was placed on the infant approximately twenty minutes before the feed was due. The data was then continuously collected prior to nappy change, for three minutes after the change, throughout the feed and for ten minutes after finishing the feed. Parents carried out a nappy change after a period of recording, the infant was then weighed and allowed to settle for three minutes prior to commencing feeding. Because infants take breaks during breast feeding, it was decided that feeding was considered to be finished if there was no sucking for ten continuous minutes. Behavioural observations were made during the time before the nappy change, one minute before commencing feeding and in the post feed period.

In those infants where there was demand feeding, the monitoring equipment was applied when mothers believed their infant to be nearing readiness for feeding (usually within the following half hour). Data were subsequently collected as described for infants on scheduled feeds.

#### **4.5.8      *Analysis***

Analysis looks for associations between the variables observed on individual infants in the study. The type of data collected supported presentation of results through descriptive summaries, correlation of trends, differences within paired samples and by repeat measures. The interval data was assumed to be normally distributed and therefore parametric statistics were applied in these circumstances; non-parametric statistics were applied to categorical data.



#### **4.5.9      *Data protection***

Physiological, behavioural and demographic data were collected and transcribed onto a readily available spreadsheet and stored according to the Data Protection Act, 1987.

## **CHAPTER 5**

# Chapter 5

## Changes in feeding pattern with increasing post menstrual age

### *5.1 Introduction*

Efficient oral feeding is the ability to consume sufficient volumes of milk to ensure normal growth and development whilst not inducing physiological instability or fatigue. To achieve this an infant strives to attain the mature sucking pattern as described in well, term infants (Gryboski, 1969). This sucking pattern is assumed to be the preferred pattern as it occurs after a biologically determined gestation and is the one which is most frequently seen. It is the mature feeding pattern of term infants which is considered the gold standard against which preterm infants are assessed in determining feeding maturity and progression.

The organisation of sucking in the well, term infant is dependent upon level of arousal and the presence or absence of milk (Wolff, 1968; Drewett, 1979). In non-nutritive sucking there is a high frequency of sucks to breaths (approximately 2:1) with occasional swallows. It is characterised by rapid bursts of sucking and short periods of pause. In nutritive sucking (bottle feeding) the within-feed pattern is quite predictable with infants having an initial continuous sucking period followed by an intermittent period where sucking bursts shorten and pause periods lengthen. During the initial continuous period of feeding there is an equal

number of sucks to swallows to breaths (Bu'Lock, 1990). As the feed progresses into intermittent sucking and pausing the swallows become less frequent with more sucks being required to initiate the swallow.

In Mathew's study (1989) of comparing feeding outcomes between breast and bottle feeding infants, he describes the initial burst of feeding the continuous sucking burst. Subsequent analysis of data is based on this distinction in feeding pattern. Woolridge (1982) gives an illustration of instantaneous milk flow at the beginning of feeding. This initial burst appears longer than any other and therefore might be considered as the continuous sucking burst. Later in the paper he reports feeding commencing in bursts and pauses, with milk flow increasing after about two minutes of feeding. The pilot data from the current study (obtained from well term infants) indicates that the mean length of the first burst of sucking is greater than the subsequent bursts. Therefore for the purposes of the current study, the first burst of sucking is considered to be the continuous burst and ensuing feeding as intermittent bursts with pauses. Data is first analysed giving an overall picture of feeding and then separated for these two periods as it would seem that greatest respiratory compromise is observed during the initial burst of sucking.

In breast feeding there is no regular pattern to feeding. Infants begin the continuous sucking phase with a 2-3 sucks per swallow and breath (pre-“let-down reflex” pattern) and then progress to a rhythmical pattern with equal distribution of each element. During intermittent feeding the pattern alters and becomes similar to the pre let-down pattern with more sucks per swallows towards the end of feeding.

The purpose of this part of the study is to describe the development of sucking patterns in breast feeding infants admitted to a neonatal unit. The infants included in this sample have limited oral feeding experience (less than one week) .

### 5.2 Sample

A convenience sample of 32 infants were selected with gestational ages ranging from 29-37 weeks (mean = 31.58 weeks, stdev. = 1.98) at birth and a post menstrual age (PMA) at time of recording between 31 and 37 weeks . Birth weight ranged from 800 grams to 3290 grams (mean = 1752 grams, stdev. = 510 grams) and weight at time of recording between 1270 grams and 3285 grams (mean = 1960 grams, stdev. = 424 grams).

PMA at time of feed (weeks)		31	32	33	34	35	36	37
Total no. of recordings		n=3	n=3	n=10	n=6	n=6	n=2	n=2
birth gestation weeks	mean	29	30	30.7	32	33.5	31	35
	stdev	0	1.7	.7	1.7	.5	2.8	2.8
birth weight grams	mean	1142	1480	1690	1748	2194	1535	2345
	stdev	173	381	186	337	624	926	947
weight at feed grams	mean	1341	1626	1909	1902	2254	2336	2547
	stdev	120	111	241	186	6605	270	406

Table 3      Summary data showing number of measurements according to PMA against mean birth gestation, birth weight and pre-feed weight

The large difference in weight reflecting the gestational and post menstrual range of 6 weeks (table 3)

All first measurements were taken within the first 7 days of commencing oral feeds. The time for commencing oral feeds was not determined by the researcher but by individual caregivers. Table 3 indicates that for most infants oral feeding was commenced within two or three weeks of birth. However the two infants measured at 36 weeks PMA appear to have a greater time delay in commencing oral feeds, approximately 5 weeks. Two explanations are offered for this:

1. their individual birth gestations were 29 and 33 weeks; the infant at 33 weeks PMA commenced oral feeds in accordance with other groups but the infant at 29 weeks gestation did not, thus influencing the group mean.
2. their birth weights were 880 grams and 2190 grams respectively . At the time of measurements their weights were 2145 grams and 2528 grams respectively and therefore caregivers may have used weight as a criterion for commencing oral feeds in the first infant. However as other groups of infants commenced oral feeding at earlier ages and lesser weights, it is assumed that the decision to commence oral feeding in this particular infant was based on individual caregiver assessment. This infant therefore had a longer delay before commencing oral feeds which effectively influenced the group mean time in commencing oral feeds.

From these 32 infants an analysis of their first feed record was made.

Maternal characteristics were ascertained from 25 mothers. Six mothers had multiple pregnancies with 5 sets of twins and 1 of triplets. Maternal age at time of delivery ranged from 21 to 39 years (mean = 30 years, stdev. = 4). Sixteen (64%) mothers were multiparous and 9 (36%) were primigravid. Of those mothers who were multiparous 10 (62.5%) had previous breast feeding experience and 6 (37.5%) no experience. Of the mothers having their first infant 6 (66.7%) had observed friends or family breast feeding but 3 (33.3%) had no previous breast feeding experience, neither observational nor promotional. Therefore many (64%) of the participating mothers had some experience of breast feeding, be it personal or observational through friends and family or media coverage.

### **5.3 Measures**

As described in chapter 2, a number of variables are required to be measured in order to describe feeding development. The three components of feeding considered here are sucking, swallowing and breathing and therefore equipment measuring these variables were utilised. Both sucking and breathing were measured using pressure sensitive pads and swallowing by auscultation. All data were monitored continuously via the DENSA pneumograph.

### **5.4 Analysis**

Systematic evaluation of the data was performed in a manner which reflected the factors/measures caregivers use to determine feeding ability. One of the factors used is the time it takes an infant to complete a prescribed volume of milk. Many staff set limits as to how long an infant

may be allowed to feed for; the assumption being that a short feed for whatever reason does not allow sufficient volume to be consumed and a long feed becomes exhausting and costly in terms of energy expenditure. In general infants are allowed to feed for approximately 20 to 30 minutes and in some cases just 5 or 10 minutes when first starting oral feeding. Therefore the data were analysed in terms of feeding time illustrating overall pattern development and frequency of the varying elements of feeding.

Evaluation of each individual feed record showed data for length of feed, number of sucks, swallows, breaths per feed, ratio between each component, number of bursts and pauses and length of bursts and pauses (figure 4). The criterion used to denote a burst of sucking was a run of sucks with an intersuck interval of less than 1.5 seconds. An interval of greater than 1.5 seconds was considered as a pause period. A pointer was inserted on the graph at the beginning and end of each burst and pause interval. The time, in seconds, for each interval was displayed on the graph and number and frequency of sucks, swallows and breaths were manually calculated. The raw data were transcribed onto a spreadsheet. Using Kaleidagraph (a graphics software package) data were graphically displayed and using Statview (a statistical software package) further analysed



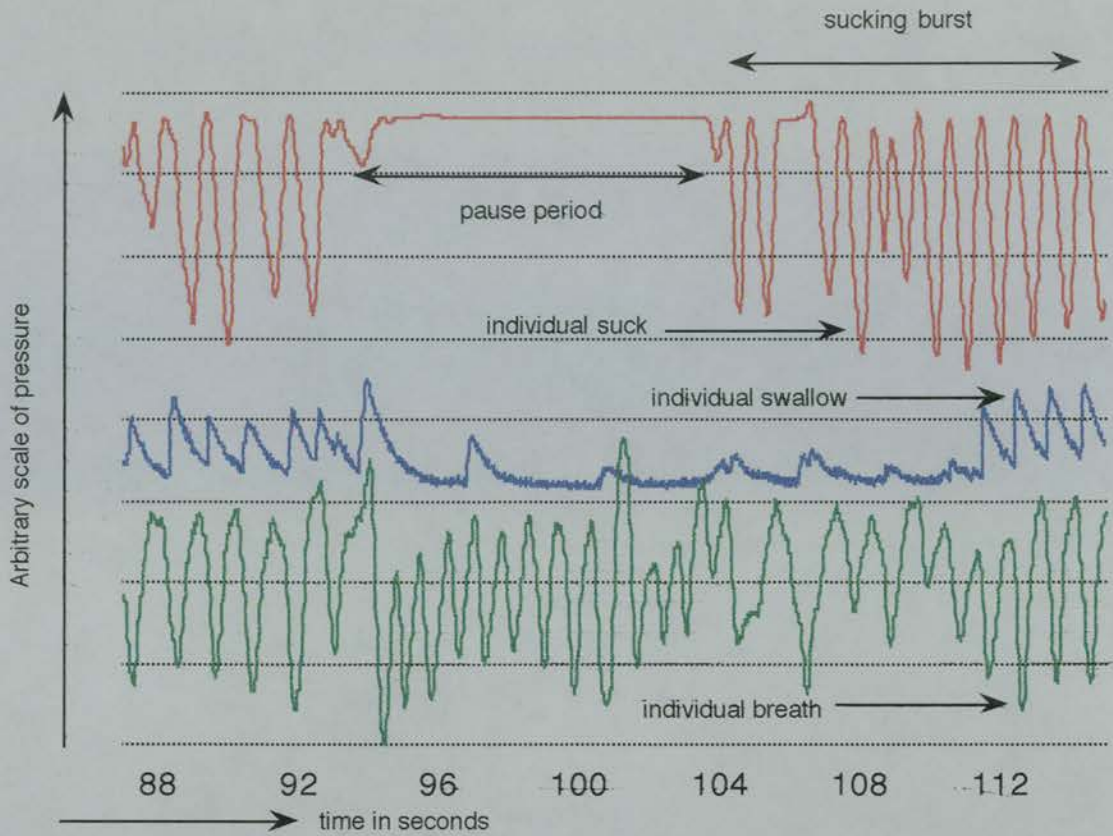


Figure 4 Illustration of a feed analysis

The data were then grouped into the post menstrual ages at time of recording. From this the mean and standard deviation and error values were calculated. As length of feeding affected frequency of sucking, swallowing and breathing, these data were also analysed as functions of time (in seconds). Statistical analyses using descriptive summaries and Pearson's Product Moment Correlation were performed on the cross sectional data to reveal changes in feeding pattern with increasing gestation and post menstrual age. Significance values of  $p < 0.05$  (\*),  $p < 0.01$  (\*\*), and  $p < 0.001$  (\*\*\*) are given.

## **5.5 Results**

### **5.5.1 Overall pattern development**

The initial analysis was performed on the cross sectional data. The first consideration was the overall pattern of feeding development. The following definitions were used to define feeding parameters:

*Total feeding time:* the length of time between the first suck and the last suck of the whole feed. Therefore the 'total feeding time' refers to the sum of the feeding time of the infants divided by the number of infants in the particular PMA group giving a 'mean total feeding time'.

*Total sucking time:* the length of time taken up with sucking in each feed. Therefore the 'total sucking time' refers to the sum of the sucking time of the infants divided by the number of infants in the particular group giving a 'mean total sucking time'.

*Continuous sucking time:* the length of time of the first sucking burst of each individual feed. Therefore the 'continuous sucking time' refers to the sum of the continuous sucking time of infants divided by the number of infants in the particular group giving a 'mean continuous sucking time'.

*Intermittent sucking time:* the length of time taken up with sucking during that portion of the feed where sucking was interspersed with pausing. Therefore the 'intermittent sucking time' refers to the sum of the intermittent sucking time of the infants divided by the number of infants in the particular group giving a 'mean intermittent sucking time'.

*Total pause time*: the cumulative length of time in between sucking bursts of intermittent feeding. Therefore the ‘total pause time’ refers to the sum of the pause time of the infants divided by the number of infants in the particular PMA group giving a ‘mean total pause time’.

The data illustrated in figure 5 indicates that with increasing PMA there was great variability in infants’ feeding times. Feeding times ranged from a few minutes to more than an hour. The mean length of feeding was unrelated to PMA. Table 4 shows the mean length of feeding in seconds for each group. The total feed time was then divided into total sucking time, which includes continuous and intermittent sucking time and total pause time.

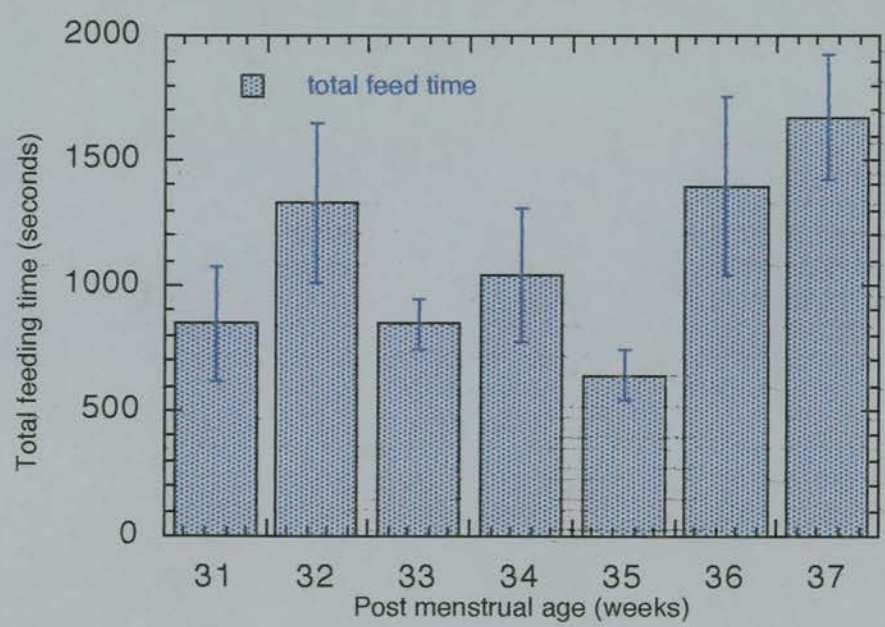


Figure 5 Mean and standard error for total feeding times at different PMAs

# POST MENSTRUAL AGE AT TIME OF FEED (weeks)

	31 n=3	32 n=3	33 n=10	34 n=6	35 n=6	36 n=2	37 n=2
FEED COMPONENT							
total feed time (seconds)							
(mean)	847	1332.67	845.7	1044.5	640.5	1398.33	1672
(s.e.)	225.71	319.54	103.49	270.32	100.69	357.70	249.04
(range)	569-1294	695-1688	423-1343	437-2144	265-904	925-1924	1423-1921
total sucking time (seconds)							
(mean)	389	244	308.8	491	312.67	485.67	704.5
(s.e.)	92.88	123.65	53.82	191.11	62.06	152.97	291.54
(range)	282-574	110-491	115-620	122-1342	120-541	248-671	413-996
continuous sucking time (seconds)							
(mean)	13.67	15.33	10.2	16.67	32.5	17.67	48 **
(s.e.)	11.2	4.84	1.33	5.43	8.4	8.73	43.0
(range)	1-36	10-25	2-18	5-34	15-68	4-28	5-91
intermittent sucking time (seconds)							
(mean)	375.33	228.67	298.6	474.33	280.17	468	656.5
(s.e.)	97.35	126.09	53.93	191.55	55.14	145.84	248.53
(range)	275-570	85-480	93-1332	104-618	95-473	244-650	408-905
total pause time (seconds)							
(mean)	458	1088.67	536.9	553.5	327.83	912.67	967.5
(s.e.)	136.92	276.42	59.0	96.71	50.04	213.52	42.5
(range)	258-720	564-1505	308-804	310-889	145-505	677-1253	925-1010

Table 4      Total feeding time subdivided into feeding components



As total feeding time was not obviously affected by PMA it may be that the proportion of sucking to pausing was altered within feeds and with increasing PMA. One might expect a fragile immature infant to spend more time in pause than in active sucking. However the data did not support this (figure 6); the mean total pause duration was variable, between 327.83 seconds and 1088.67 seconds, with no trend being seen to suggest a decrease in total pause time with increasing PMA (table 4). As pause time did not decrease it may be that the phases of feeding were altered with increasing PMA. The phases of feeding are the two which have previously been described, continuous sucking and intermittent sucking with periods of pause.

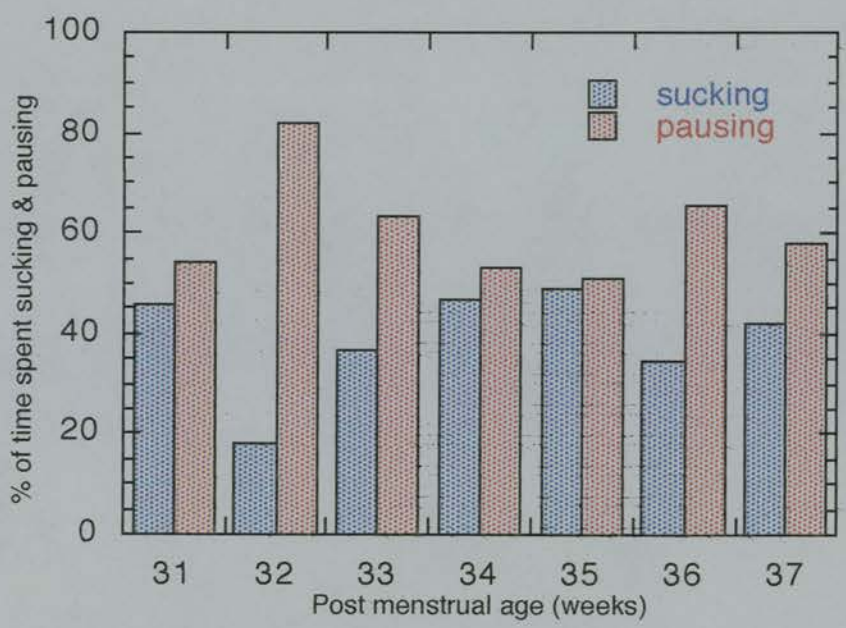


Figure 6 Proportion of time spent sucking and pausing

When comparing continuous sucking time to intermittent sucking time there was a significant increase with PMA in the continuous sucking time ( $p < 0.01$ ) but no such trend was seen in intermittent sucking time. The significant effect was mainly due to the values at 35 and 37 weeks PMA (table 4). These two values were not related to total length of feeding; the percentage of total feeding time spent in continuous sucking was greater in these two groups than any other (table 5).

POST MENSTRUAL AGE AT TIME OF FEED (weeks)						
31	32	33	34	35	36	37
n=3	n=3	n=10	n=6	n=6	n=2	n=2
FEED COMPONENT						
% continuous sucking						
1.6	1.15	1.21	1.6	5.07	1.26	2.87
% intermittent sucking						
44.3	17.16	35.31	45.41	43.74	33.47	39.26
% pause						
54.1	81.69	63.48	52.99	51.19	65.27	57.87

Table 5    Percentage of time in spent in different feeding phases when compared to total feeding time

The intermittent feeding phase was divided into sucking bursts and pause periods. The total number of bursts and pauses were always the same. This was because intermittent feeding began with the first pause after the continuous sucking phase and ended with the last sucking burst. As shown in figure 7, there was no pattern in the occurrence of

bursts or pauses but there was a general trend towards greater number of bursts and pauses with increasing PMA. This trend had little effect on mean burst duration. The duration of sucking bursts was similar throughout groups, indicating infants were able to pace themselves irrespective of burst number, feed length or PMA (table 6).

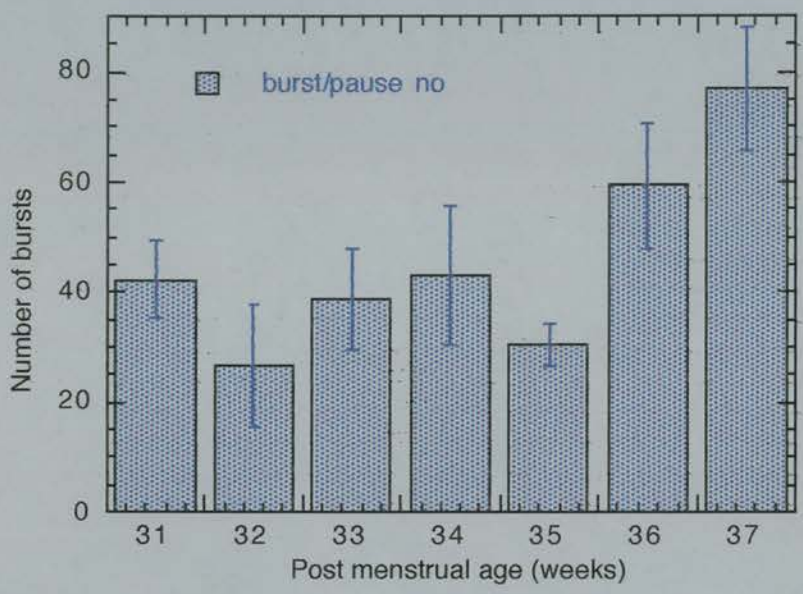


Figure 7 Mean and standard error of number of bursts per feed

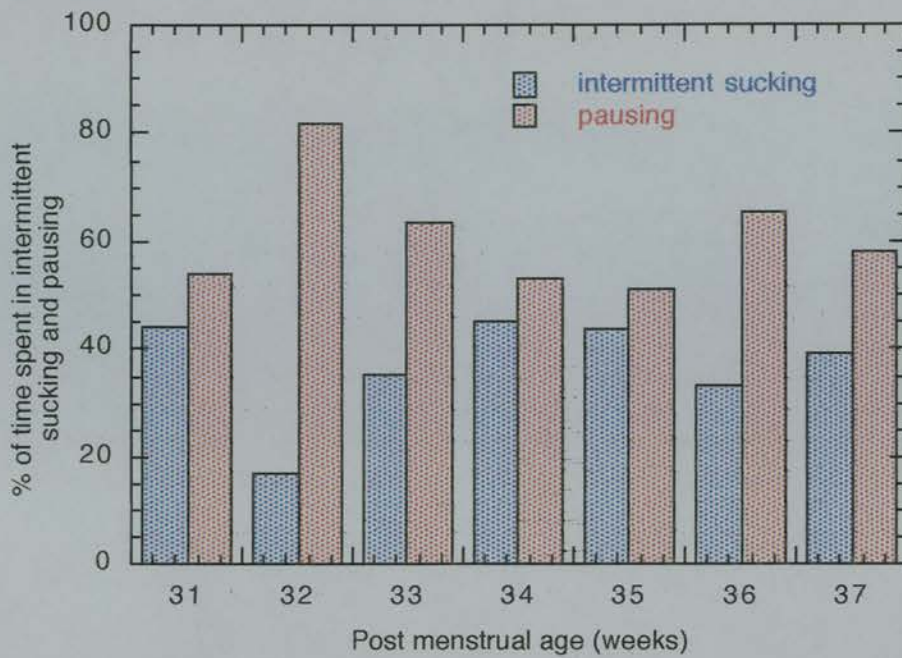
Where total feeding time was short, one might anticipate few burst/pause epochs and where total feeding time was longer, more might be anticipated. This was supported in all groups except infants at 32 weeks. When comparing total feeding time for 32 and 33 week PMA groups one could see that 32 week infants fed for longer and therefore the expectation was for them to have more epochs (table 4). However fewer occurred and therefore there must have been a disproportionate time spent either in sucking or in pausing at 32 weeks PMA (table 6 & figure 8).

POST MENSTRUAL AGE AT TIME OF FEED (weeks)

	31	32	33	34	35	36	37
	n=3	n=3	n=10	n=6	n=6	n=2	n=2
FEED COMPONENT							
intermittent sucking time (seconds)							
(mean)	375.33	228.67	298.6	474.33	280.17	468	656.5
(s.e.)	97.35	126.09	53.93	191.55	55.14	145.85	248.53
(range)	275-570	85-480	93-1332	104-618	95-473	244-650	408-905
burst no.							
(mean)	42.33	26.67	38.9	43.17	30.5	59.33	77
(s.e.)	6.99	11.05	9.24	12.59	4.06	11.32	11.0
burst time (seconds)							
(mean)	8.64	7.83	9.18	10.22	9.34	7.61	8.23
(s.e.)	.82	1.22	1.56	2.61	1.68	1.19	2.05
total pause time (seconds)							
(mean)	458	1088.67	536.9	553.5	327.83	912.67	967.5
(s.e.)	136.92	276.42	59.0	96.71	50.04	213.52	42.5
(range)	258-720	564-1505	308-804	310-889	145-505	677-1253	925-1010
pause no.							
(mean)	42.33	26.67	38.9	43.17	30.5	59.33	77
(s.e.)	6.99	11.05	9.24	12.59	4.06	11.32	11
pause time (seconds)							
(mean)	10.35	62.87	19.26	15.06	10.89	15.31	12.91
(s.e.)	1.45	36.99	3.44	1.59	1.2	1.17	2.4

Table 6      Total time spent in sucking and pausing with mean number and duration of bursts and pauses





*Figure 8* Intermittent feeding- % of time spent in sucking and pausing

The mean distribution of sucking, swallowing and breathing during bursts of sucking as well as breathing during pause periods were considered [table 3, appendix]. Significant differences were established with increasing PMA in the mean number of sucks ( $p = 0.05$ ) and swallows ( $p = 0.01$ ) per burst but not breaths/burst or breaths/pause.

#### 5.5.1.1 Discussion

Although others have characterised infants with suboptimal feeding skills as having long pauses and an inability to continue sucking in a rhythmical pattern (Dubignon, 1980; Case-Smith, 1988), the data presented in the current study indicates that no assumption can be made

on feeding ability from the length of feeding or ratio of sucking to pausing. Caesar (1982) demonstrated that in bottle feeding preterm infants, feeding efficiency was related to gestational age and duration of feeding experience, suggesting infants with poor feeding skills required longer to feed.

However the results of Meier (1985) showed that breast feeding infants spent considerably more time in general feeding activities than bottle feeding infants. She indicated that length of feeds were associated with the pre-feed level of wakefulness and the amount of non-nutritive feeding behaviour engaged by breast feeding infants during feeding. Further, the study showed that pause time remained lengthy across PMA. Drewett (1979) and Lucas (1979) also demonstrated in breast feeding infants that pause duration and frequency were variable but it increased towards the end of feeding.

The proportion of sucking to pausing between the groups was not predicted. The expectation was for the fragile infants to become more easily fatigued by the effort of sucking and therefore spend more time in pause. However this was not demonstrated by the data and pause time as a percentage of total feeding time varied little between the groups. The exception to this was the 32 week PMA group. This lack of effort may add weight to an argument presented by Inoue (1995). Inoue (1995) suggested that as breast milk flow is governed by a reflex of secretion and ejection, there is little need for active suction or expression. Therefore, although preterm infants make sucking movements, these may not be the primary mechanism for milk retrieval, milk flow being governed by maternal hormone secretion and breast stimulation and not necessarily by strength

of suction. If this is the case, infants who are not generating sucking pressure will not become overly fatigued.

No account could be made for the short sucking time or long pause time experienced by the infants at 32 weeks PMA. It may be that these infants behaved in an appropriate way for their post menstrual age but when compared against those measured at 31 weeks, those at 32 weeks appeared to do poorly. They spent little time in sucking and long periods in pause. The few infants who were measured at 31 weeks PMA represent the total number of infants who were suckling and available for recruitment in the time allowed for data collection. Because there were so few it may suggest that they were exceptional infants for their PMA.

The reduced sucking behaviour seen in the two infants measured at 36 weeks post menstrual age may have been influenced by the one infant being born at 29 weeks gestation which was 4 weeks younger in gestational age than the other. Also this infant took longer, approximately 7 weeks, to commence oral feeding than any other infant. The average post menstrual age before commencing feeding was 2 weeks. The effect of this one infant's results on the other may have been to dampen down the overall results on feeding ability.

In conclusion, the length of feeding remained variable with no particular pattern being established with increasing PMA. Continuous sucking time appeared to increase with PMA but this was marginally reflected in the total time spent at feeding. There was no discernable pattern to the amount of time spent in sucking or in pausing.

The lack of pattern formation in any of these feed parameters may be due to:

- a. variation in infants appetite. At any time of measurement infant perception of hunger may vary considerably thereby affecting the length of time at feeding,
- b. breast feeding infants being more interactive during feeding, having extended periods of pause in which to socialise,
- c. the inability of caregivers to visualise the amount of milk a breast feeding infant consumes and therefore caregivers cannot prolong or terminate a feed to meet the prescribed volume and
- d. the small number of infants in each group. The data may not be representative of feeding at a particular PMA and therefore extreme caution is emphasised in the interpretation of results.

### ***5.5.2 Feeding elements as events per second***

The second consideration in analysis was how the phases and elements of feeding vary and change with increasing PMA (table 7). As the overall pattern of feeding development did not satisfactorily describe feeding ability, it appeared to be more informative and useful to describe the data as occurrences in time and therefore the elements of sucking, swallowing and breathing are expressed as events per second.

It can be seen from table 7 that total feeding time was not significantly increased with PMA; still there was a trend to longer feeding episodes in the more mature infants. With increasing PMA the number of sucks/second increased substantially although not significantly from .83/second to 1.14/second ( $r^2 = 0.04$ ,  $df\ 30$ ,  $p = 0.26$ ); swallowing frequency

increased even more so from .39 to .66 swallows/second ( $r^2 = 0.118$ ,  $df = 30$ ,  $p < 0.05$ ). Thus not only did the more mature infants suck faster but they also obtained more milk and therefore swallowed more frequently. The diversity in swallows/second across the groups had little effect on breathing frequency as breaths/second were maintained during sucking between .88 and .96 per second except in the 31 week PMA group where they were .72 breaths/second. However breathing frequency throughout feeding, that is during sucking and pausing, was remarkably stable, varying very little between .91 and 1.09 breaths per second (table 7).

POST MENSTRUAL AGE AT TIME OF FEED (weeks)

	31	32	33	34	35	36	37
	n=3	n=3	n=10	n=6	n=6	n=2	n=2
FEED ELEMENT							
total feed time (seconds)							
(mean)	847	1332.67	845.7	1044.5	640.5	1398.33	1672
(s.e.)	225.71	319.54	103.49	270.32	100.69	357.70	249.04
(range)	569-1294	695-1688	423-134	437-2144	265-904	925-1924	1423-1921
breaths/second (total feed)							
(mean)	.93	.97	.98	1.02	1.09	1.0	.91
(s.e.)	.03	.03	.03	.07	.07	.09	.01
sucks/second							
(mean)	.83	.99	1.07	1.1	1.0	1.12	1.14
(s.e.)	.07	.13	.11	.08	.05	.07	.007
swallows/second							
(mean)	.39	.24	.39	.53	.46	.31	.66 *
(s.e.)	.06	.04	.04	.06	.0	.02	.11
breaths/second (during sucking)							
(mean)	.72	.96	.88	.88	.96	.91	.93
(s.e.)	.08	.03	.05	.03	.04	.06	.07

*Table 7*      Feed parameters of sucking, swallowing and breathing  
expressed as frequencies per second during total feeding  
time

### **5.5.2.1     *Differences between continuous and intermittent feeding patterns***

During both continuous and intermittent sucking phases the total number of sucks were largely dependent upon the time of the phase and the relationship between each element. The ratios between sucking and swallowing, breathing and swallowing and sucking and breathing are represented in figures 9 and 10 [tables 4 & 5 appendix].

The ratio between sucking and breathing was variable both between groups and the two sucking phases. No pattern could be distinguished between the ratios and phases with increasing PMA. The number of sucks/swallow showed a uniform change between continuous and intermittent phases with fewer sucks required to achieve a swallow during intermittent sucking. The number of breaths/swallow also varied between the phases but this appeared to be related to an assumed milk flow and swallow frequency (table 8) [ tables 4 & 5 appendix]. Where milk flow was high (represented by swallows/second) the number of sucks and breaths/swallow were low and where low the reverse (figures 9 & 10). For example, where swallows/second were .12, breaths/swallow were 10.33 but where swallows/second were .66, breaths/swallow were 1.46.



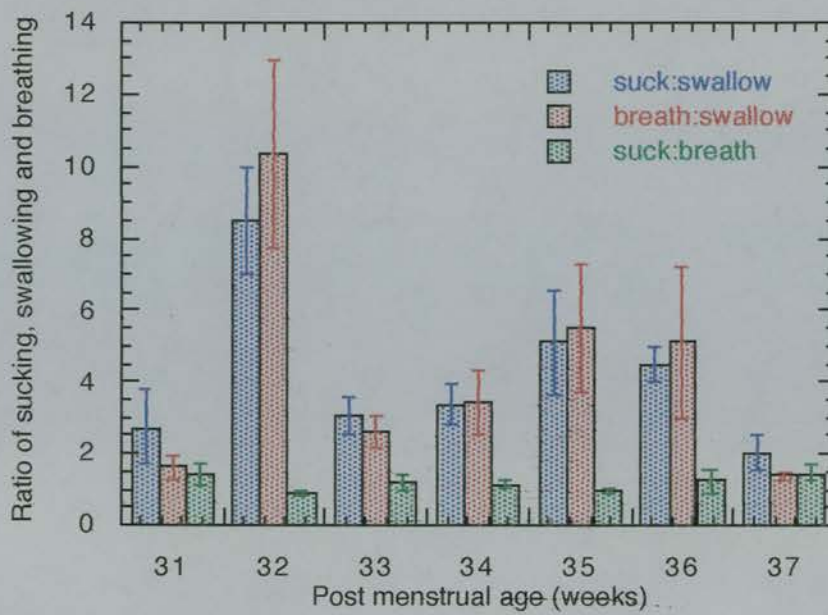


Figure 9 Ratio of sucking, swallowing and breathing at different PMAs during continuous feeding

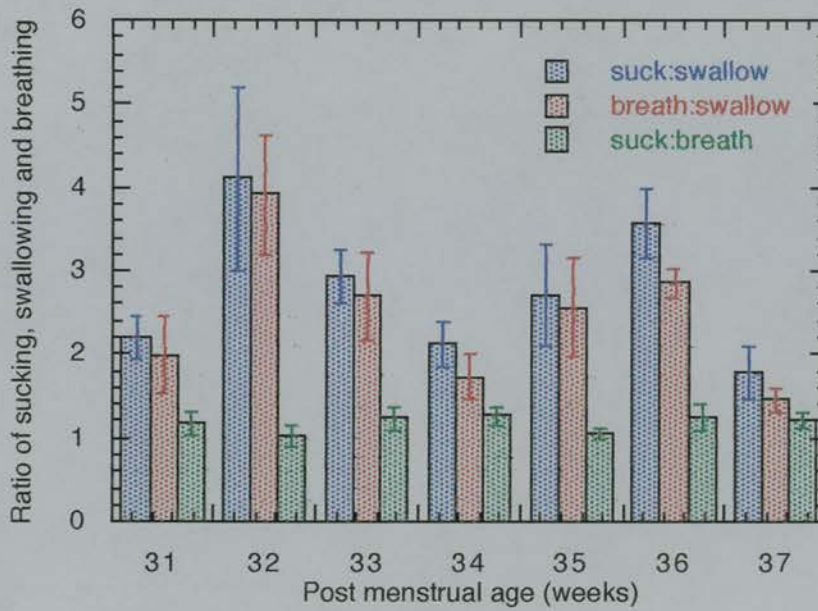


Figure 10 Ratio of sucking, swallowing and breathing at different PMAs during intermittent feeding



When comparing the groups during continuous sucking, sucking frequency did not appear to be related to swallow frequency (table 8). There was no pattern to suggest rapid sucking occurred in the presence of low milk flow or slow sucking during high milk flow (figures 11 & 12). Although there was no significant difference between sucking frequency during continuous and intermittent phases, most groups increased their sucking frequency during intermittent sucking and it was only at 31 and 34 weeks PMA that a decrease in frequency occurred. Despite this slight variation, the number of swallows/second increased uniformly between the phases. Therefore no matter how fast or slow an infant sucked during the intermittent phase, more swallows were elicited than in continuous sucking. Moreover swallows/second increased significantly ( $r^2 = 0.121$ ,  $df = 30$ ,  $p < 0.05$ ) with increasing PMA during intermittent sucking whereas, although they increased during continuous sucking this was only due to the high frequency of the 37 week PMA group. The increase in swallow frequency during intermittent sucking appeared to have little effect on breathing frequency. The number of breaths/second were reduced during intermittent sucking in all groups except the 37 week PMA group but this reduction was not significant.

POST MENSTRUAL AGE AT TIME OF FEED (weeks)							
	31	32	33	34	35	36	37
	n=3	n=3	n=10	n=6	n=6	n=2	n=2
FEED PARAMETER							
continuous time sucking (seconds)							
(mean)	13.67	15.33	10.2	16.67	32.5	17.67	48
(s.e.)	11.2	4.84	1.33	5.43	8.4	8.73	43.0
sucks/second							
(mean)	.97	.94	1.07	1.2	.98	1.07	1.06
(s.e.)	.05	.15	.37	.17	.14	.16	.09
swallows/second							
(mean)	.3	.12	.36	.34	.28	.15	.56
(s.e.)	.32	.07	.19	.23	.16	.13	.22
breaths/second							
(mean)	.76	1.12	.96	1.08	1.01	.96	.76
(s.e.)	.14	.17	.11	.08	.08	.25	.16
intermittent sucking time (seconds)							
(mean)	375.33	228.67	298.6	474.33	280.17	468	656.5
(s.e.)	97.35	126.09	53.93	191.55	55.14	145.85	248.53
sucks/second							
(mean)	.83	.99	1.07	1.09	.99	1.12	1.14
(s.e.)	.07	.14	.11	.08	.05	.07	.007
swallows/second							
(mean)	.39	.26	.39	.55	.48	.32	.66 *
(s.e.)	.06	.05	.04	.07	.11	.03	.12
breaths/second							
(mean)	.72	.96	.89	.87	.94	.91	.94
(s.e.)	.08	.02	.05	.03	.05	.06	.07

Table 8                      Elements of feeding expressed as frequencies per second  
during continuous and intermittent sucking phases

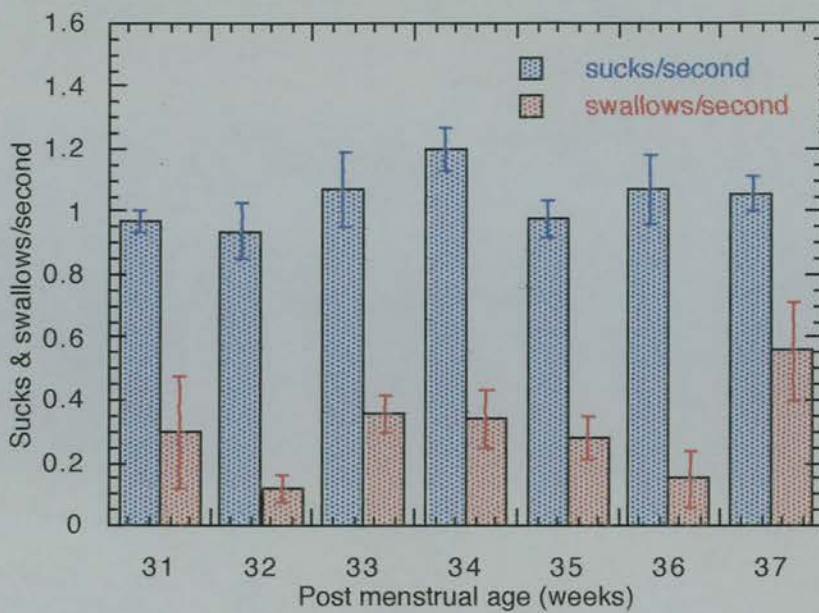


Figure 11 Frequency of sucking and swallowing during continuous feeding



Figure 12 Frequency of sucking and swallowing during intermittent feeding

### **5.5.2.2      *Alteration to breathing pattern during intermittent sucking and pause***

Episodes of pause are associated with recovery in ventilation. Again the number of breaths are related to the total length of feed and are therefore not an indication of feed organisation. Because of this breathing is also expressed as a function of time (table 9).

This study has shown breathing frequency to be affected throughout the different phases of feeding (table 9) and this is represented in figures 13 and 14. Breaths/second are dependent upon the proportion of time spent in sucking and swallowing. However during periods where there was no active sucking, breathing was altered to effect restoration in frequency, giving a mean breaths/second between .91 and 1.09 (table 9 and figure 14).

In immature infants (groups <35 weeks PMA) breathing during pause was altered in response to the swallow frequency of intermittent sucking; a low swallow frequency resulted in slower breathing during pause (tables 8 and 9). However the same swallow frequency at 31 and 33 weeks PMA showed a different effect on breathing with the 33 week PMA group breathing more slowly than the 31 week PMA group (table 9). This may represent a maturational step by the 33 week group whereby fewer measures are undertaken by infants in rectifying disturbances in ventilation brought on by swallowing.

POST MENSTRUAL AGE AT TIME OF FEED (weeks)

31	32	33	34	35	36	37
n=3	n=3	n=10	n=6	n=6	n=2	n=2

FEED ELEMENT

whole feed

(mean)	.93	.97	.98	1.02	1.09	1.0	.91
(s.e.)	.03	.03	.03	.07	.07	.09	.01

O<sub>2</sub> saturation %

(mean)	94.13	95.91	96.74	96.98	95.18	97.63	99.04
(s.e.)	.29	.13	.11	.1	.14	.11	.07
(range)	67-100	85-100	86-100	84-100	83-100	89-100	86-100

during sucking

(mean)	.72	.96	.88	.88	.96	.91	.93
(s.e.)	.08	.03	.05	.03	.04	.06	.07

continuous sucking

(mean)	.76	1.12	.96	1.08	1.01	.96	.76
(s.e.)	.14	.17	.11	.08	.08	.25	.16

intermittent sucking

(mean)	.72	.96	.89	.87	.94	.91	.94
(s.e.)	.08	.02	.05	.03	.05	.06	.07

during pause

(mean)	1.12	.98	1.03	1.1	1.21	1.04	.88
(s.e.)	.05	.03	.03	.03	.1	.71	.04

Table 9 Breaths per second during the whole feed, continuous and intermittent phases. Oxygen saturation (O<sub>2</sub>) given only for whole feed

In infants >34 weeks PMA, the influence of swallowing during intermittent sucking on breathing frequency during pause was less apparent. Of interest are the infants at 35 and 37 weeks PMA. Those at 35 weeks PMA breathed more quickly during pause than any other group. The only difference noted was that this group spent the greatest proportion of feed in continuous sucking and the least in pause. Perhaps the combination stressed the infants sufficiently to breathe rapidly during pause.

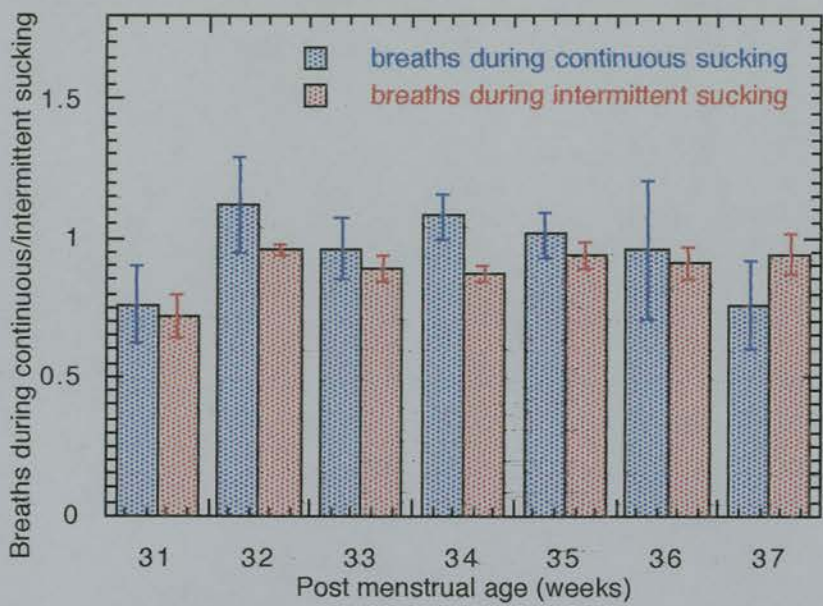


Figure 13 Breaths/second during continuous and intermittent sucking



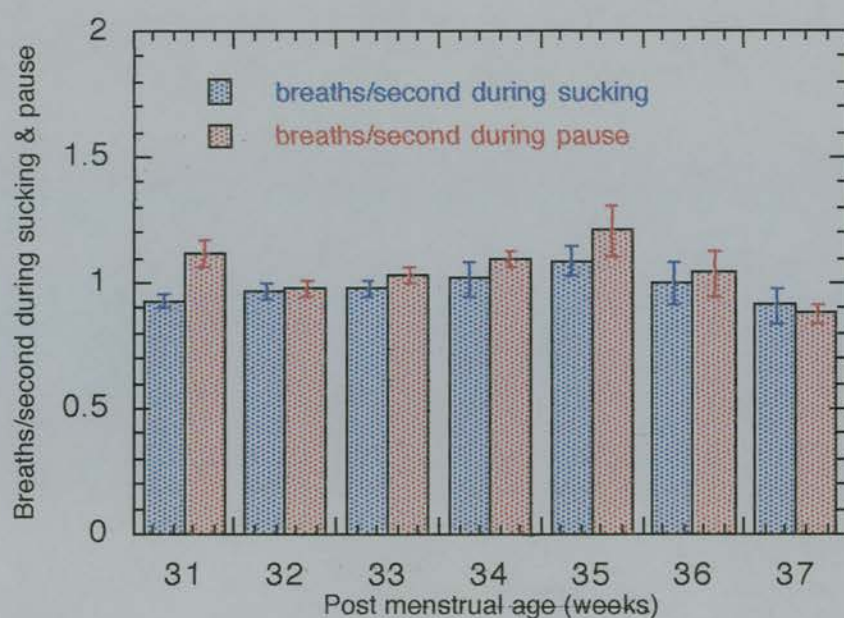


Figure 14 Breaths/second during sucking and pause

Infants at 37 weeks PMA, who despite having the highest swallow frequency during intermittent sucking showed a marked reduction in breathing frequency during pause. This may have been due to maturity or lactation.

## 5.6 Discussion

Analysis of the elements of breast feeding in premature infants has not previously been reported in this way and therefore comparisons can only be made indirectly to studies involving term breast feeding infants and both term and preterm bottle feeding infants. The differences in results seen in this study and those of others (Drewett, 1979; Woolridge, 1982; Weber, 1986; Mathew, 1989 and Medoff-Cooper, 1991) may stem from the differences in infant maturity, feeding method and methodologies.

During feeding the ratio of sucking, swallowing and breathing on a 1:1:1 or 2-3:1:1 later in the feed as reported by Weber (1986) was not achieved [tables 4 & 5, appendix]. However the study by Weber (1986) reported difficulty in positioning the ultrasound scanner head during breast feeding and this was only achieved once a sucking rhythm had been established. It may be therefore that prior to this, an uneven sequence of sucking, swallowing and breathing was experienced. The findings of this study are more akin to those of Bu'Lock (1990) who reported changes in bottle feeding infants as they matured; they showed a 1:1:1 linkage between sucking, swallowing and breathing with increasing PMA.

It has been suggested that during the course of a feed, milk flow and behavioural state alters and this brings about a change in sucking frequency (Drewett, 1979; Bowen-Jones, 1982). In a study by Woolridge (1982), sucking pace and milk flow are described as changing after approximately 2 minutes of feeding. During this initial period, infants sucked at a "moderate" (pg. 371) pace separated by bursts and breathing pauses. After this, sucking slowed as milk flow increased; towards the end of feeding sucking pace quickened and this was found to be related to milk flow.

The continuous sucking phase of the current study only refers to the first burst of sucking. Therefore direct comparisons with Drewett (1979) and Woolridge (1982) cannot be made. In spite of this a change was seen in the ratio and frequency of sucking, swallowing and breathing between continuous and intermittent phases. It was not surprising that generally more sucks/swallow were seen between continuous and intermittent phases, as at this time infants were stimulating the let-down reflex.



However the fewer sucks/second seen in continuous sucking were unexpected, as Drewett (1979) had suggested a low milk flow resulted in a higher suck frequency. Mathew (1989) also demonstrated a higher suck frequency during continuous than during intermittent sucking. An explanation for this difference might be that during continuous sucking, milk flow changed from none to significant amounts. Sucks/swallow and sucking frequency altered accordingly but by grouping together the data of the whole burst for analysis, these subtle differences were lost. Therefore the findings reported here are in contrast to those of Drewett (1979) and Mathew (1989).

The increase in milk flow that was seen with intermittent sucking may have resulted from release of the let-down reflex, and an increase in sucking strength. An increase in sucking frequency was also a feature of this phase. Although measurements of sucking strength and milk flow have not been established in breast feeding premature infants it is not inconceivable that with experience and increasing PMA, sucking becomes stronger. In association with this is the developmental factor that more mature infants have greater muscle mass and motor control and may therefore achieve a higher sucking amplitude sooner than more immature infants.

Infants at 31 weeks PMA behaved differently to any other group (table 8). In this group the sucking frequency slowed between continuous and intermittent phases. This may have occurred in response to the high swallow frequency of continuous sucking and therefore follow the sucking pattern described by Drewett (1979) and Bowen-Jones (1982). It may also have been a compensatory response to respiratory compromise (table 9).

Related to this increase in swallowing was a decrease in breathing rate. By altering sucking frequency the infants may have attempted to reduce milk flow and therefore swallow frequency thus allowing more time for breathing. This phenomenon of swallowing interrupting breathing concurs with other studies (Mathew, 1989; Koenig, 1990 & Al-Sayed, 1994) and therefore was not unexpected.

The purpose of pause is for respiratory recovery and in this study the effect of pause was to bring about stability in breaths per second throughout the whole feed (table 7 & figure 15).

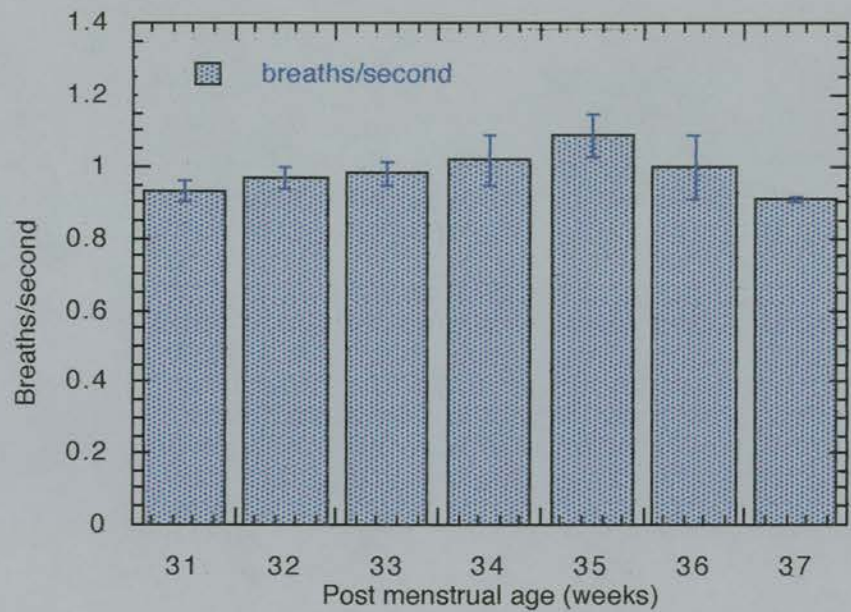


Figure 15 Breaths/second during total feed at different PMAs.

This was achieved throughout the groups. Clearly infants at 32 weeks PMA showed little alteration in breathing frequency between continuous and intermittent sucking and pause (table 9). The most probable reason is the infrequent occurrence of swallowing in this group (table 8). Again

this supports the notion of swallowing influencing quality of breathing. What is not apparent is the reason for low milk flow at this time.

At 37 weeks PMA the increase in swallowing during intermittent sucking did not adversely affect breathing as the breathing rate in pause was slower than during sucking suggesting no need for recovery (table 9). A possible explanation is that these infants were generally more robust and mature and therefore not taxed by the feeding experience. Another might be that despite the swallow frequency, lactation was not well established.

Mothers of infants in groups 31 to 36 weeks PMA had between 12 and 42 days to initiate and maintain lactation. The amount of milk they produced during manual expression and deposited in the neonatal unit storage facilities indicated a moderate to good milk supply; the mothers of the 37 week group had a maximum of only 6 days to establish a milk supply. Therefore if milk supply was limited in the 37 week group, respiratory recovery was not necessary during intermittent sucking. This was also offered as an explanation in Mathew's study (1989) where the effects of feeding on breathing were examined in infants less than 5 days old. In respect of the current study the increase in sucking frequency that was seen between continuous and intermittent phases would also support an explanation of reduced lactation.

When considering the effect breathing during pause has on breathing during the whole feed, one can see that it maintains breaths/second between .91/second and 1.09/second thus helping to sustain a steady breathing pattern throughout feeding (table 7). This suggests that even the most immature infants in this sample can bring about respiratory

recovery during breast feeding. This would support the findings of Meier (1988) whose breast feeding studies with preterm infants demonstrated little variation in oxygen levels during feeding as measured via a transcutaneous probe. The results of this study show that premature infants during breast feeding behave in a mature manner in so much as they may attempt to reduce milk flow by variation in sucking frequency. The resulting reduction in swallow frequency limits the potential for compromise in ventilation. However the data in table 9 suggests infants in the 31 week PMA group were unable to maintain ventilation despite breathing regularly and altering sucking and swallowing frequency.

In conclusion this study has shown that within the first week of oral feeding:

1. the more mature infants demonstrated a faster sucking rate and increased swallowing frequency than the immature infants.
2. Breathing rate was greater during continuous sucking than intermittent sucking in all infants except those of the 37 week PMA group. Similarly breathing rate was greater during pause than during sucking in all infants except those of the 37 week PMA group. Oxygen saturation appeared less variable in the more mature infants.
3. With increasing PMA there was a significant increase in mean sucks/burst and even greater significance to mean swallows/burst.

This pattern is similar to that found by others in both breast and bottle feeding infants (Meier, 1987; Medoff-Cooper, 1992) and this feature of feeding may be a better indicator of infant development and ability. It

appears that immature infants are not compromised by oral feeding but gestational age improves the efficiency of oral feeding.

## **CHAPTER 6**

# Chapter 6

## Organisation of feed parameters within individual feeds

### *6.1 Introduction*

The summary data presented in the previous chapter do not adequately describe the dynamic changes which occur within each feed. These temporal variations are unique to the individual and if measured over a period of time might better explain feeding development and organisation. However the difficulty persists in defining organisation. Sucking patterns emerge with increasing post menstrual age but these appear to be specific to individuals.

In Meier's work (1988) breast feeding is described as becoming more organised with increasing PMA. Organisation is measured by the length of sucking bursts and the number of sucks within each burst. Drewett (1979) describes breast feeding as being a continuum between nutritive and non nutritive sucking within the same feed. He defines bursts of sucking as being episodes containing sucks of less than 1.3 seconds apart and pause as being periods of longer duration between sucks. In addition sucking bursts are characterised as shortening whilst pause episodes as both lengthening and becoming more frequent as feeding progresses.

The purpose of this part of the study is to describe the within feed variation of premature infants admitted to the neonatal unit.



6.2      *Method*

Data from the same 32 infants as has previously been reported on were utilised to describe individual within feed changes (table 10). The data were continuously collected as previously described (Chapter 4) for the duration of each feed using the Densa pneumograph and SNAPSHOT software.

PMA at time of feed (weeks)		31	32	33	34	35	36	37
total no. of recordings		n=3	n=3	n=10	n=6	n=6	n=2	n=2
birth gestation (weeks)	mean	29	30	30.7	32	33.5	31	35
	stdev	0	1.7	.7	1.7	.5	2.8	2.8
birth weight (grams)	mean	1142	1480	1690	1748	2194	1535	2345
	stdev	173	381	186	337	624	926	947
weight at feed (grams)	mean	1341	1626	1909	1902	2254	2336	2547
	stdev	120	111	241	186	605	271	406

Table 10      Summary data showing number of measurements according to PMA tabulated against mean birth gestation, birth weight and pre-feed weight

Feeds were individually analysed into the varying components. The number of sucking bursts and pause periods and their length in seconds were manually counted from the displayed data. Likewise the number of sucks, swallows and breaths per burst and breaths per pause were also estimated. A pre-feed score of feeding ability and readiness was also calculated from combining an adapted Infant Breast feeding Assessment Tool (chapter 4)



with the Anderson Behavioural Assessment Scale [table 2, appendix]. These data are tabulated [table 6 appendix] giving mean and standard deviation values where appropriate. Statistical analyses using descriptive summaries, Pearson's Product Moment correlation coefficient, Spearman's correlation coefficient and f-ratio were performed on individual feeds.

## **6.3 Results**

### **6.3.1 Sucking patterns**

The data presented here indicate that sucking patterns are variable and unique to individual infants. Qualitative descriptions of feeds at varying PMAs may highlight more fully organisation in the elements of feeding. Shown in figure 16 are several feeding graphs illustrating different sucking patterns at varying post menstrual ages. The upward direction of the trace from baseline indicates lowering of the jaw and therefore a suck occurrence. The oscillations between the sucks are caused by breathing movements and are correlated as breaths with the respiband trace.

What becomes most apparent is the development of clearly defined sucking bursts. At 31 weeks PMA the sucking burst is evident but there is little rhythm or smoothness to sucking. Individual sucks are relatively lengthy and the time between sucks within bursts moderately extended. At 33 weeks PMA sucking bursts are more easily identified and there appears to be a little more rhythm and regularity to sucking. By 35 weeks PMA sucking bursts are clearly defined and although they are brief in length they are regular. At 37 weeks PMA the sucking bursts are lengthy. Sucks are congruent with a definite flow giving an impression of evenly timed feeding.

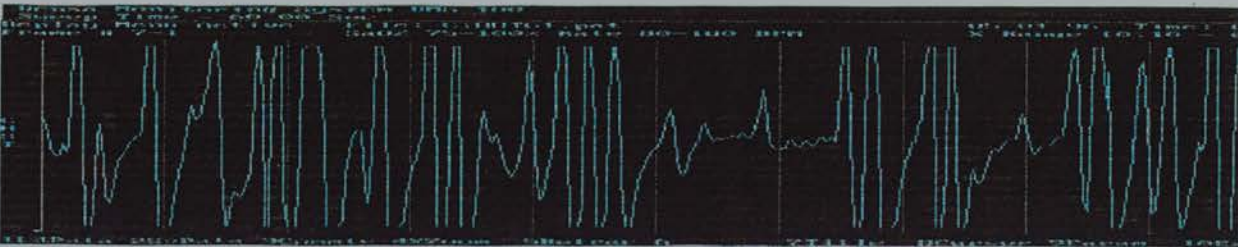
PMA. code	burst mean & s.d.	time (secs) (range)	Pearson correlation coefficient r <sup>2</sup> df p	pause mean & s.d.	time (secs) (range)	Pearson correlation coefficient r <sup>2</sup> df p
31.1	3.0	0.27 (1-26)	.173 37 <0.01 neg	11.0	9.04 (2-49)	.024 36 0.35 -
31.2	9.15	9.37 (1-42)	.121 32 <0.05 neg	7.82	8.22 (3-50)	2.421E-4 31 0.93 -
31.3	10.0	10.44 (1-44)	.017 53 0.32 -	12.71	19.46 (2-135)	.028 52 0.21 -
32.4	8.46	6.71 (3-25)	.121 11 0.24 neg	125.42	164.2 (11-564)	.133 10 0.24 neg
32.5	7.0	9.02 (2-48)	.152 47 <0.01 neg	14.5	67.78 (2-464)	.043 46 0.15 neg
32.6	6.5	5.32 (1-24)	.024 20 0.49 pos	31.0	54.82 (3-259)	.091 19 0.18 pos
33.7	7.4	10.12 (1-60)	.017 59 0.31 pos	12.55	14.95 (3-66)	.04 58 0.12 pos
33.8	7.54	10.25 (1-51)	.001 16 0.92 -	7.8	8.05 (2-45)	.27 15 <0.05 pos
33.9	21.85	11.65 (2-46)	.051 92 <0.05 neg	39.47	58.61 (5-265)	.005 91 0.48 -
33.10	8.65	7.43 (2-32)	.028 19 0.46 neg	30.24	77.84 (4-397)	.008 18 0.7 neg
33.11	9.05	9.49 (2-31)	.07 18 0.25 neg	17.85	18.54 (1-84)	.006 17 0.75 -
33.12	5.65	3.61 (1-24)	.004 39 0.68 -	8.65	20.08 (2-192)	.22 38 <0.01 neg
33.13	4.45	2.53 (1-14)	.03 81 0.11 pos	7.22	15.92 (2-127)	2.138E-4 80 0.89 -
33.14	7.24	4.08 (1-15)	.074 19 0.23 pos	27.94	35.08 (3-127)	.001 18 0.92 -
33.15	11.7	17.65 (1-85)	.437 24 <0.001 neg	17.2	25.81 (1-110)	.099 23 0.12 pos
33.16	8.21	6.4 (1-27)	.003 12 0.85 -	23.69	26.06 (3-92)	.011 11 0.73 neg

Table 11 Mean and s.d. measurements of burst and pause intervals within individual feeds. Pearson's correlation coefficient given - individual burst/pause time plotted sequentially according to feed length; neg = negative correlation, pos = positive correlation, - = no correlation (PMA 31-33 weeks; continued).

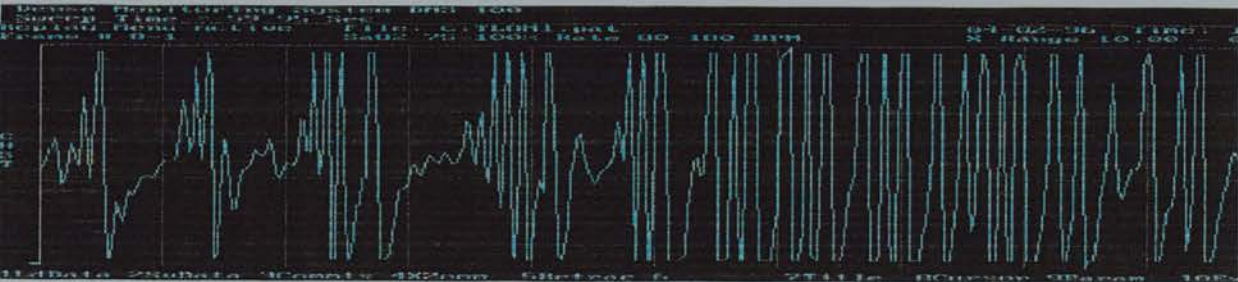
PMA. code	burst mean & s.d.	time (secs) (range)	Pearson correlation coefficient $r^2$ df p	pause mean & s.d.	time (secs) (range)	Pearson correlation coefficient $r^2$ df p
34.17	15.23	11.34 (4-90)	.183 85 0.001neg	9.33	4.34 (2-20)	.029 84 0.11 pos
34.18	20.29	15.94 (2-58)	.013 22 0.59 neg	16.09	14.48 (4-69)	.037 21 0.37 neg
34.19	8.16	5.74 (1-33)	.101 78 <0.01 neg	11.25	21 (2-179)	.001 77 0.77 -
34.20	6.72	6.01 (1-22)	2.917E-4 29 0.92 -	16.0	26.6 (3-146)	.001 28 0.85 pos
34.21	4.88	3.31 (1-12)	.262 23 <0.01 neg	18.92	23.22 (1-110)	.001 22 0.89 -
34.22	7.06	8.36 (1-34)	.307 16 <0.01 neg	18.24	21.78 (3-84)	.01 15 0.7 pos
35.23	8.76	14.79 (1-72)	.156 23 <0.05 pos	13.08	4.95 (2-130)	.032 22 0.4 pos
35.24	11.9	17.56 (2-82)	.12 18 0.13 neg	12.7	6.32 (5-28)	.065 17 0.07 pos
35.25	17.45	17.11 (2-68)	.004 29 0.72 neg	12.1	9.12 (3-40)	.008 28 0.64 neg
35.26	9.53	11.9 (1-52)	.126 42 <0.01 neg	8.77	7.91 (2-40)	.011 41 0.51 pos
35.27	4.44	5 (1-25)	.286 24 <0.01 neg	5.58	3.1 (2-14)	.065 23 0.22 pos
35.28	7.37	3.65 (1-17)	.093 41 <0.05 neg	12.02	9.1 (3-50)	.11 40 <0.05 pos
36.29	8.83	7.6 (1-39)	.003 74 0.63 -	16.71	32.93 (2-250)	3.834E-6 73 0.98 -
36.30	5.64	4.65 (1-27)	.001 42 0.84 -	15.74	14.62 (3-59)	.001 41 0.86 -
37.31	11.07	13.56 (1-91)	.167 87 <0.001neg	10.39	28.89 (2-274)	.001 86 0.8 -
37.32	6.16	4.48 (1-20)	.043 65 0.09 neg	15.3	47.86 (3-392)	.017 64 0.29 pos

Table 11 Mean and s.d. measurements of burst and pause intervals within individual feeds. Pearson's correlation coefficient given - each time interval (burst & pause) plotted sequentially according to feed length; neg = negative correlation, pos = positive correlation (PMA 34-37 weeks; continued).

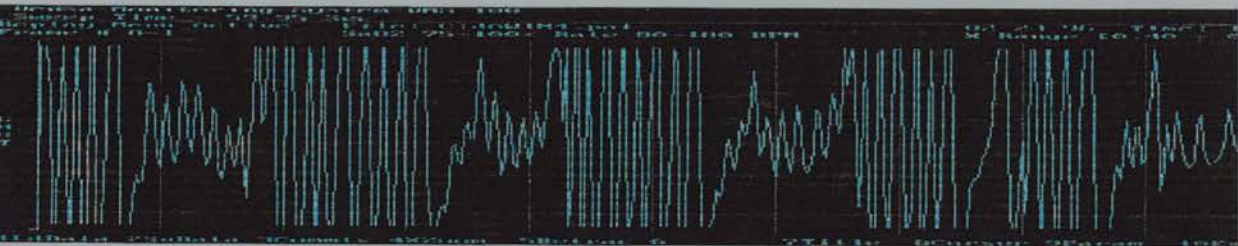
Sucking at 31 weeks PMA



Sucking at 33 weeks PMA



Sucking at 35 weeks PMA



Sucking at 37 weeks PMA

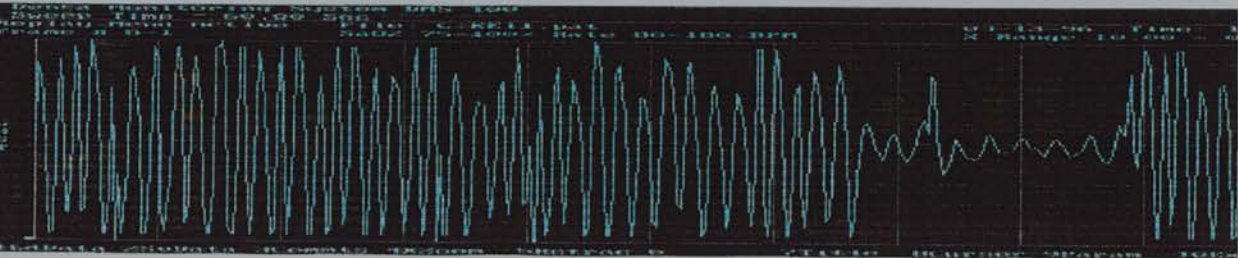


Figure 16    Graphs representing different sucking patterns

Figures 17 a, b, c and d represent four individual traces of 60 second snapshots. Channel labels indicating sucking (suck), swallowing (swall)



and breathing (resp) are respectively displayed along the vertical axis. Swallowing is noted by either an upward or downward deflection in the trace. Occasionally the deflection does not return to baseline but continues in the opposite direction giving the impression of two swallows. However the continuity between the up and downward movement indicates that it is a single swallow.

It is difficult to interpret the effect swallowing has at 31 weeks PMA (figure 17a) because sucking movement at this PMA is hesitant and jerky. It does not appear to interfere with sucking at 33 weeks PMA (figure 17b), 35 weeks PMA (figure 17c) or 37 weeks PMA (figure 17d). However sucking and swallowing is seen to have a profound effect on breathing in all four groups.

As the infant takes a breath there is an upward movement in the trace and with breathing out a reverse action. The depth and quality of breathing can only be assessed individually as each are dependent upon transducer site and tightness of the restraining band.

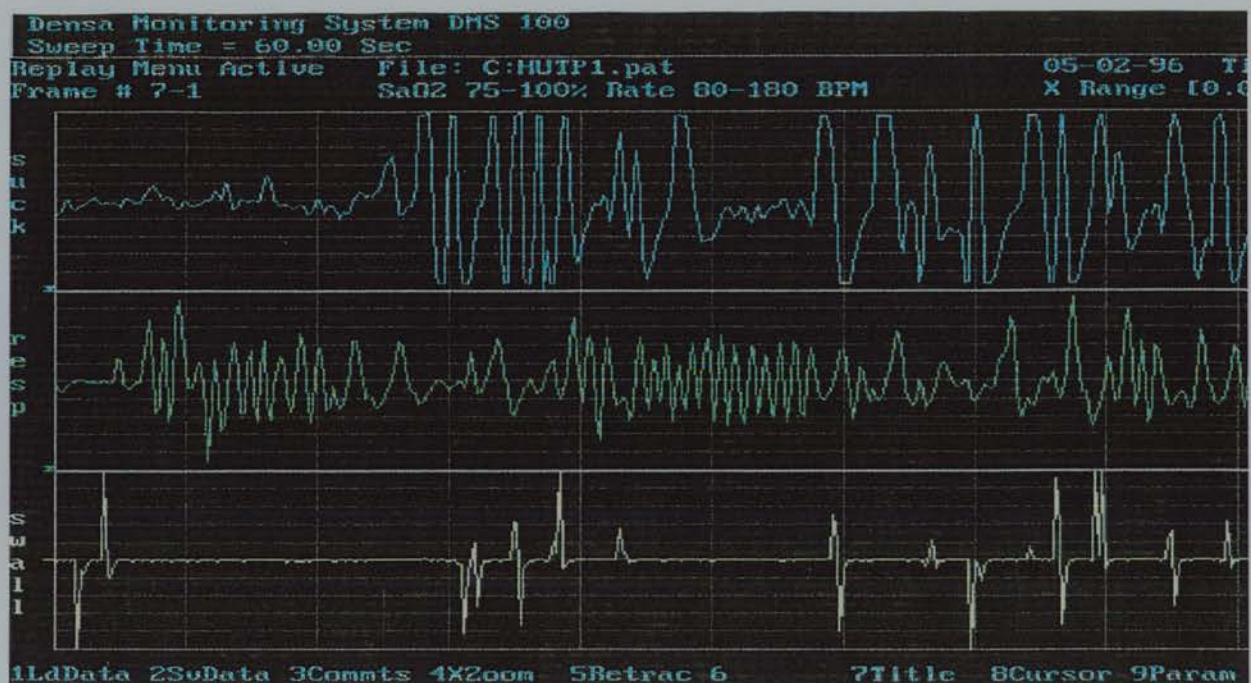


Figure 17a Example of sucking, breathing and swallowing at 31 weeks PMA

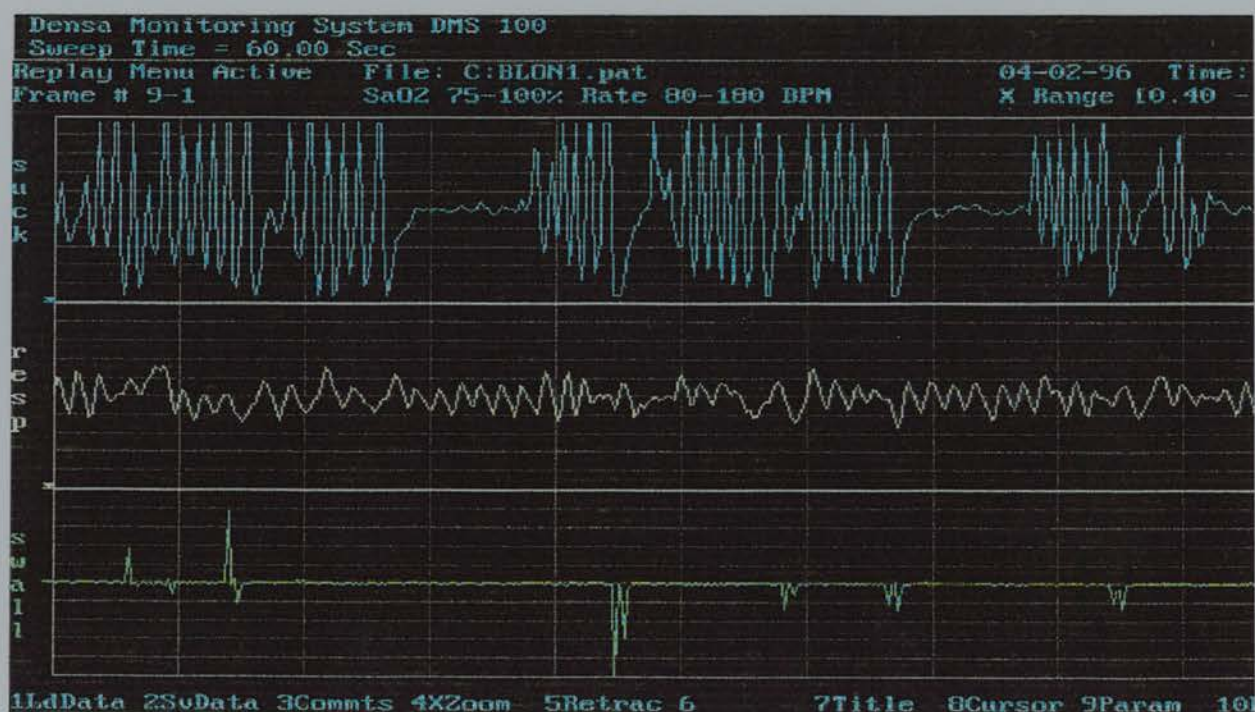


Figure 17b Example of sucking, breathing and swallowing at 33 weeks PMA



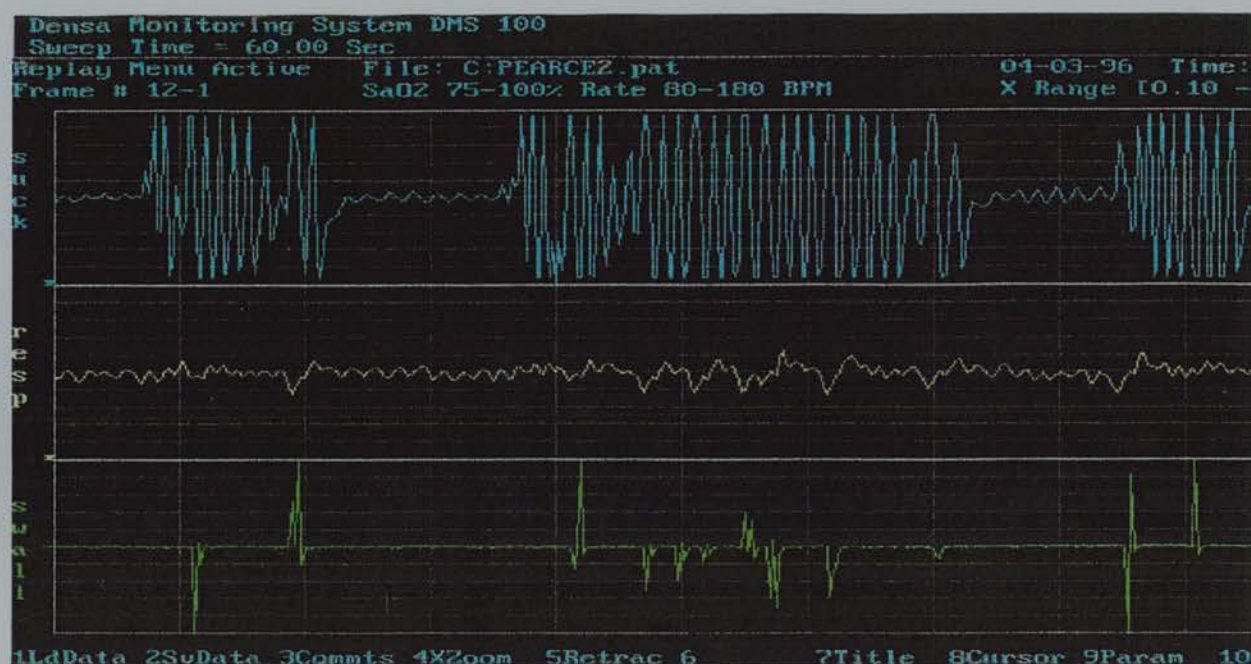


Figure 17c Example of sucking, breathing and swallowing at 35 weeks PMA

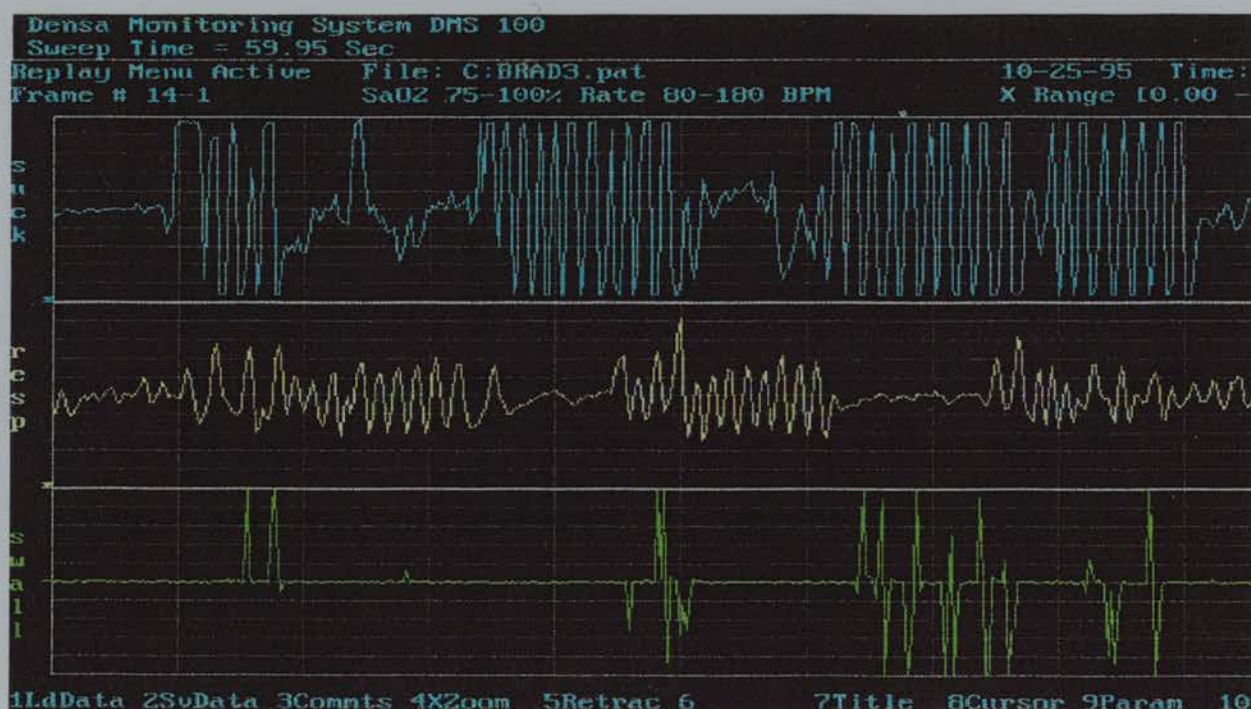


Figure 17d Example of sucking, swallowing and breathing at 37 weeks PMA

At all ages breathing during pause is generally regular although at times and for brief spells there is periodicity. Breathing during sucking, be it nutritive or otherwise, is disrupted; the frequency, continuity and quality



of inspiration to expiration is not the same as that during pause. The interruption of breathing by swallowing varies; the traces of all infants show destabilisation in breathing. No particular PMA appears more compromised than another.

Figure 17a shows extensive disruption to breathing both in frequency and continuity between inspiration and expiration. At the beginning of the graph one can see delayed swallowing, not associated with sucking, causing apnoea for a brief spell. Breathing then appears to become rhythmical but prior to commencing sucking there is a slowing in rate. As the infant begins to suck and swallow breathing becomes disjointed; the rhythm, depth and smoothness are lost. The infant regains control during pause, only to become irregular again during sucking and swallowing.

Figure 17b shows a similar disruption to breathing albeit to a lesser degree. This may be due to a reduced swallow frequency. Figure 17c shows an infant at 35 weeks PMA demonstrating lack of smoothness in the breathing cycle during nutritive sucking. The frequency of breathing is consistent with that of the pause periods. Figure 17d shows a more mature infant continuing to have slightly irregular breathing during nutritive sucking but also showing respiratory pause. This was mostly associated with a high frequency in swallowing. During the pause periods there is there both depth and uniformity to breathing.

### 6.3.2 *Burst/pause pattern*

In examining the data from the 32 feed records (table 4) no real pattern could be detected from the total length of feeding or frequency (table 6) and mean lengths of sucking bursts and breathing pauses within each feed (table 11). Twenty feeds showed burst time decreasing during feeding, 5 showed burst time increasing and no difference in 7 feeds; pause time increased during feeding in 13 feeds, decreased in 7 feeds and no difference being seen in 12 feeds (table 11).

The mean length of sucking bursts was significantly reduced over the course of feeding in 12 of the 32 feeds; the level of significance (Pearson's Product Moment correlation coefficient) being between  $p < 0.05$  and  $p < 0.001$ . These 12 feeds were distributed throughout the range of PMAs and not clustered to any particular group. A single sample t-test (two tailed) indicating whether the correlation coefficients of mean burst time were significantly different from zero showed that overall there was a relationship between mean burst time and length of feed ( $t = 7.548$ ,  $df 31$ ,  $p < 0.001$ ).

However despite the burst time shortening in just over a third of feeds, the mean number of sucks/second were unaffected in all but 3 feeds [table 7, appendix]. In 2 feeds (PMA code 31.1 and 32.5), mean sucks/second increased significantly in accordance with decreasing mean burst time and in the third feed (PMA code 33.15) mean sucks/second decreased during the course of feeding. The mean sucks/second increased during feeding in 2 other feeds; these were unrelated to changes in mean burst time. Mean breaths/second during sucking were also affected in 7 feeds. In 4 feeds

(PMA code 34.19, 34.22, 35.26 and 35.27) mean breaths/second significantly decreased as bursts became shorter. In 2 feeds (PMA code 33.12 and 34.18) mean breaths/second decreased and another (PMA code 34.17) increased but these were not related to mean burst length. Therefore, generally no matter how long or brief each sucking duration lasted, the number of sucks/second were not significantly altered. In 1 infant (PMA 53.23) the burst time increased significantly over the course of feeding ( $p < 0.05$ ) but again this did not influence the mean frequency of sucks or breaths/second.

Some changes in the mean duration of pause were also seen as feeds progressed (table 11). Changes in 2 feeds (PMA code 33.8 and 35.28) were associated with pause periods significantly increasing in length ( $p < 0.05$ ) and 2 feeds (PMA code 33.12 and 34.17) with pause periods significantly decreasing in length ( $p < 0.05$  and  $p < 0.01$ ). A single sample t-test (two tailed) indicating whether the correlation coefficients for mean pause time were significantly different from zero showed that overall there was a relationship between mean pause time and length of feed ( $t = 5.577$ ,  $df 31$ ,  $p < 0.001$ ).

In 1 feed, mean breaths/second decreased as mean pause time decreased and in another as pause increased. In only 1 of these 4 feeds was a shortening of sucking burst time associated with lengthening of pause time (PMA code 35.28) but mean sucks and breaths/second were not affected by this burst/pause pattern. Although mean breaths/second were altered in other feeds these were unrelated to trends in pause length [table 7, appendix]. With all other feeds the length of pause periods were similar throughout the individual feed.

Thus no real pattern or trend was established with regard to burst/pause periods within individual feeds or between infants of varying PMA's. Sucking and breathing frequency were also individual to infants and not related to PMA.

### **6.3.3 *Milk flow - sucking and breathing***

Term infants are reported to initiate the let-down reflex and thus a high milk flow within the first few minutes sucking (Drewett, 1979). In the current study the time between commencing sucking and the occurrence of at least 2:1 suck:swallow ratio, indicating a high milk flow, were considered. In 9 feeds a suck:swallow ratio of 2:1 was achieved within the first burst of sucking and immediately on sucking [tables 6, appendix]. This pattern was seen in some infants in the 31, 33, 35 and 37 week groups. In the remaining 23 infants the high suck:swallow ratio was achieved between 12 and 899 seconds of feeding. For many of these infants it occurred within one or two bursts of sucking. However five infants took between 4 and 13 sucking bursts to achieve a high milk flow. In most feeds bursts of non-nutritive sucking were observed. No pattern was found as to the length of non-nutritive sucking bursts nor when they occurred within each feed.

Not all sucking bursts were associated with swallowing [table 6, appendix-PMA code 34.18, 35.22 and 35.24 have no non-nutritive sucking events]. In all but 3 feeds there were periods of non-nutritive sucking at some point during the feed; that is sucking bursts at any time during the feed in which no swallows occurred. The mean sucks/second in 24 of these 29

feeds were higher during the non-nutritive bursts than during the nutritive sucking bursts [tables 6, appendix]. In the remaining 5 records, 4 had fewer mean sucks/second during non-nutritive sucking and the other showed no difference in the mean sucks/second. In order to see if infants altered their sucking and breathing rate in the expected manner, in response to milk flow, paired t-tests were used to compare the overall mean sucks/second and breaths/second for 29 infants during nutritive and non nutritive sucking. The findings of the t-tests (one tailed) indicated that overall infants sucked faster ( $t = 3.822$ ,  $df = 28$ ,  $p < 0.001$ ) as well as breathed faster ( $t = 2.385$ ,  $df = 28$ ,  $p < 0.01$ ) during non nutritive sucking.

#### ***6.3.4 Breathing during sucking and pausing***

One of the observations of the recorded traces was an apparent difference in breathing regularity during sucking bursts and pause periods. Some of these are illustrated in figures 17a, b, c and. During pause breathing pattern appears to be more consistent and rhythmic than during sucking. The understanding is that the irregularity in breathing seen during nutritive sucking is due to interruption by swallowing (Al-Sayed, 1994; Koenig, 1990).

The initial data analysis showed that mean breaths/second were higher during pause periods than during sucking bursts in all but 2 records [table 7, appendix]. A paired t-test comparing the rate of breathing during sucking and pause was carried out on all the data. The finding of the t-test (one tailed as breathing during pause was generally higher than during sucking) showed that infants significantly altered their breathing strategy during pause presumably to accommodate the effects of swallowing during

sucking ( $t= 6.356$ ,  $df\ 31$ ,  $p <.0.001$ ). This would suggest that infants use breathing rate as a method of adjusting respiratory needs but as tidal volume was not assessed this cannot be confirmed. As the visual traces indicated possible irregular breathing during sucking bursts but not during pause periods, it was decided to test the significance of the regularity comparing the variances in breaths/second during these two periods using  $f$ -ratios (table 12).

<b>PMA code</b>	<b>f-ratio</b>	<b>df</b>	<b>p value</b>	<b>PMA code</b>	<b>f-ratio</b>	<b>df</b>	<b>p value</b>
<b>31.1</b>	1.70	158, 457	<0.01	<b>34.17</b>	1.00	1128, 852	ns
<b>31.2</b>	1.00	254, 306	ns	<b>34.18</b>	0.78	382, 439	ns
<b>31.3</b>	1.98	446, 728	<0.01	<b>34.19</b>	0.87	798, 511	ns
<b>32.4</b>	3.45	100, 1422	<0.01	<b>34.20</b>	1.81	177, 481	<0.01
<b>32.5</b>	0.42	467, 1142	ns	<b>34.21</b>	3.31	122, 588	<0.01
<b>32.6</b>	1.92	132, 590	<0.01	<b>34.22</b>	2.82	120, 411	<0.01
<b>33.7</b>	2.56	248, 551	<0.01	<b>35.23</b>	2.13	213, 387	<0.01
<b>33.8</b>	2.78	649, 707	<0.01	<b>35.24</b>	0.68	422, 229	ns
<b>33.9</b>	0.82	848, 475	ns	<b>35.25</b>	1.06	507, 380	ns
<b>33.10</b>	0.83	749, 226	ns	<b>35.26</b>	1.00	476, 472	ns
<b>33.11</b>	0.66	328, 131	ns	<b>35.27</b>	0.92	132, 93	ns
<b>33.12</b>	1.14	404, 777	<0.05	<b>35.28</b>	6.25	325, 583	<0.01
<b>33.13</b>	1.07	222, 466	ns	<b>36.29</b>	1.81	665, 1429	<0.01
<b>33.14</b>	1.32	134, 449	<0.05	<b>36.30</b>	3.77	227, 747	<0.01
<b>33.15</b>	0.66	230, 313	ns	<b>37.31</b>	1.00	782, 996	ns
<b>33.16</b>	3.24	81, 354	<0.01	<b>37.32</b>	2.60	356, 922	<0.01

Table 12      Significance between mean breaths/second during nutritive sucking and pause using f-ratios Abbreviation: ns = not significant

It would appear that breathing duration was more irregular during sucking bursts than pause periods in 17 out of the 32 records.



### ***6.3.5 Swallow frequency and pre-feed behavioural score***

Swallow frequency is an indication of milk flow; milk flow being dependent upon supply through the maintenance of lactation, let-down reflex and efficiency of breast emptying. Therefore it is one measure or indication of maternal/infant feeding performance.

Studies have indicated that level of arousal prior to feeding, influences how well an infant feeds (Gill, 1988; Matthew, 1988). In the current study no relationship was found between level of arousal prior to feeding assessed with the Anderson Behavioural State Scale (ABSS) [table 2, appendix] ) and feeding ability as indicated by sucks and swallows/second (Spearman's correlation coefficient  $z = 0.924$ ,  $df\ 30$ ,  $p = 0.35$  and  $z = 1.87$ ,  $df\ 30$ ,  $p = 0.06$  respectively). This may be because the score reflected the optimal or highest score in the 2 minutes prior to feeding and not the immediate 30 seconds before feeding. Sucking and swallowing are also indicators of maternal milk flow and therefore because the the ABSS is a reflection of infant behaviour and not maternal influence/performance an adapted Infant Breast feeding Assessment Tool (Matthew, 1988, chapter 4) in conjunction with the ABSS was used to score individual infants' behaviours of feeding readiness and ability (see page 76).

There was no relationship between PMA and the score indicating behaviour of feeding readiness and ability (Spearman's correlation coefficient  $z = 0.795$ ,  $df\ 30$ ,  $p = 0.424$ ) [table 6, appendix]. However this was not unexpected as many of the scoring features are behaviours which are practised in utero e.g. hand-to-mouth movements, rooting and sucking and infants are seldom encouraged by caregivers to attempt oral feeding

unless they are awake and alert. As sucks and swallows/second were increased with increasing PMA (table 8), feeding performance as denoted by these two variables was measured against the feeding behavioural score.

A trend was found between sucks/second and behavioural score but this was only significant at the  $p < 0.05$  level (Spearman's correlation coefficient  $z = 2.025$ ,  $df\ 30$ ). However swallow frequency was significantly associated with a high score (Spearman's correlation coefficient  $z = 4.177$ ,  $df\ 30$ ,  $p < 0.001$ ). Thus it would appear that behaviours related to feeding ability are more clearly associated with feeding performance as indicated by swallows/second. It may be that the mature infant does not necessarily have to display the pre-feeding behaviours of readiness and ability to obtain a high milk flow. The greater muscle tone and motor control seen in these infants may improve their sucking reflex so that as a consequence of maturation, they are not so dependent upon wakefulness for successful feeding.

## **6.4 Discussion**

The graphs presented show a variety of burst/pause patterns and sucking organisation (figures 17a, b, c & d). In addition they illustrate the effects sucking and swallowing have on breathing. Each pattern is individual but with increasing post menstrual age there is a trend towards synchrony in sucking and breathing.

The within feed development of sucking bursts and breathing pauses appears to be tailored to individual infants. Although there was a trend

towards shorter bursts and longer pause periods in some feeds these were not distinguished by any identified criteria. It could not be said from the data presented that burst/pause organisation changed as a result of increasing PMA; this being in contrast to the breast feeding studies in premature infants of Meier (1988) and term infants of Drewett (1979). These differences may arise from the use of different measuring techniques, level of alertness and behaviours of feeding ability in individual infants.

The role of non-nutritive sucking during feeding is difficult to understand. It does not appear to occur during bottle feeding but is prevalent in the current study during breast feeding. The differences in sucks/second between nutritive and non-nutritive sucking were similar to those previously reported (Wolff, 1968, Hack, 1985). Wolff (1968) showed that infants sucked faster during non-nutritive sucking than during nutritive sucking. However, where Wolff and Hack showed increasing numbers of sucks/burst, sucks/second and less time between bursts, this could not be demonstrated in the current study. In their studies, infants were offered blind teats (teats without holes) and therefore infants did not control milk delivery. In the current study non-nutritive sucking occurred spontaneously during normal feeding; infants controlled sucking to influence the frequency of milk flow. It is speculated that non-nutritive sucking during breast feeding may arise from:

- a. an initial inhibition of milk flow, as in pre let-down flow. In this current study a number of infants achieved a high milk flow directly on sucking. All mothers were encouraged to use the techniques of breast massage and hand expression prior to infant sucking. However these activities predominantly occurred in

mothers of immature infants and therefore the results seen may reflect individual mothers' preparation for breast feeding and not individual infants' abilities. For this reason some non-nutritive sucking was observed at the beginning of some feeds;

- b. a general decrease in milk flow; as the feed progresses milk flow decreases and this initiates rapid sucking to increase supply. In addition, the fast sucking rate may serve to re-establish an adequate negative pressure within the breast to draw milk into the nipple (Woolridge, 1986);
- c. a compensatory mechanism whereby infants manipulate milk flow to regulate/correct respiratory compromise. By continuing the sucking action, milk is brought into the nipple, but by limiting the flow with tongue obstruction, breathing is allowed to occur with no impedance.

The disruption to breathing during nutritive sucking could not be quantified because tidal volume was not measured. It was not surprising that increases were seen in breathing rate during pause periods. As has been reported in the previous chapter the number of breaths per second were reduced during active sucking but when considering the whole feed, breaths per second were remarkably stable (figure 15). The reduction in breathing frequency during sucking is similar to that reported by Mathew (1989) and Koenig (1990) but where their term infants experienced ventilatory compromise during the course of feeding the infants in the current study (except those at 31 weeks PMA) did not. Mathew (1989) showed that the difference between breast and bottle feeding infants lay in the timing of inspiration and expiration. In his study bottle feeding caused a significant decrease in breathing frequency with decreased

inspiratory time and a prolonged expiratory time. Breast feeding showed a decrease in inspiratory time but breathing frequency and expiratory time were not significantly altered from the control period. Thus overall breathing was not as affected during breast feeding as during bottle feeding. Infant position during feeding was not considered as a contributing factor but Mathew did concede that milk flow may have influenced the pattern of breathing.

Mothers in the current study were routinely shown several positions on how to hold their infant during breast feeding. In all, infants were placed with their whole body turned towards their mother's chest thus creating a stable platform against which the infant lay. In addition the posture was almost horizontal with the infants' necks slightly extended to achieve the correct chin position for grasping the nipple.

Posture has been considered in the coordination of swallowing and breathing (McFarland, 1994). In this study of adults in upright and horizontal positions, swallowing was found to occur in different phases of breathing. During the upright position, swallowing frequently occurred late in expiration, prolonging the phase but in the horizontal position, swallowing most often occurred soon after inspiration causing little alteration to expiratory time. In the ultrasonographic study by Weber (1986) swallowing was also found to occur at the transition or in the early stages of the inspiratory phase of breathing. Unfortunately the authors did not comment on possible differences between breast and bottle feeding infants.

The alternation between sucking and pausing in the current study regulated breathing to give an overall breathe duration of between 0.91 and 1.09 breaths/second. It may be that the horizontal position adopted for breast feeding influenced the timing of swallowing to occur in the transition or early expiratory phase of breathing; thus swallowing neither prolonged expiration nor decreased breathing frequency by inducing apnoea. However to achieve a steady breathing pattern throughout feeding, a change had to occur during pause. It may be that inspiratory time and/or expiratory time during pause was decreased and this resulted in the increase in breaths/second seen during pause.

In conclusion the data presented in this study indicates that organisation of individual feeding remains variable; but as previously indicated, many factors affect feeding performance and therefore the variation may be due to these factors and not to immaturity. These findings are in contrast to others who have demonstrated particular within-feed changes (Drewett, 1979). There was no overall trend in burst time shortening or pause time lengthening as feeds progressed. The differences in results between the current study and those of others could have arisen through the use of different methodologies, subjects and feeding techniques. Even though the data in the current study do not show expected trends, the graphs show improved rhythm and timing which may be secondary to maturation of the central nervous system.

## **CHAPTER 7**



# Chapter 7

## Longitudinal within-subject changes in feeding organisation

### *7.1 Introduction*

The cross sectional data of chapter 5 demonstrates that feeding organisation is not related to how long an infant feeds (table 4). Even the separate components of sucking and pausing are not proportionally related to increasing post menstrual age (table 7). This may have been due to inherent differences between individuals and as there were only small numbers in each group, these differences appeared unrelated. However when looking at the elements of sucking, swallowing and breathing as functions of time a trend is seen in the organisation and development of feeding with increasing PMA.

Further analysis with individual repeat measures may take into account individual variation and indicate a degree of difference in development and organisation. This part of the study aims to examine changes within-subjects in the feeding elements which occur over time.

### *7.2 Method*

Repeat measurements were made in a number infants from 31 weeks PMA giving 55 records: the distribution of measurements being: 6 infants with 2 consecutive records, 7 infants with 3, 2 infants with 4 and 4

infants with 14 intermittent measurements made between 31 weeks PMA and term (table 13).

	No. of infants	No. of records	Total no. of feed
Single records	13	13	
<i>Consecutive records</i>	<i>6</i>	<i>2</i>	<i>12</i>
	<i>7</i>	<i>3</i>	<i>21</i>
	<i>2</i>	<i>4</i>	<i>08</i>
<i>Intermittent</i>		<i>4</i>	<i>14</i>

Table 13    Total number and distribution of single and *repeat* measurements obtained from 32 infants.

For those having repeat measurements, there were at least 6 days between recordings. It was anticipated that all infants would have repeat measurements from commencing oral feeds until full breast feeding was established. This was not achieved on 21 occasions for the following reasons:

- 4 infants were transferred to another hospital,
- 7 mothers were unable to meet with the researcher at the agreed times, (of these 1 missed 1 week's measurement, 2 missed 2 weeks and 4 missed 3 weeks; those missing 3 weeks were discontinued from the study),
- 1 infant became significantly unwell with oral feeds being stopped and 9 mothers chose to discontinue breast feeding.

Nineteen infants from the original 32 were measured on more than one occasion. Gestational ages ranged from 29-37 weeks (mean= 31.58 weeks,

stdev. = 1.98) at birth and post menstrual age (PMA) at time of recording between 32 weeks and term. Birth weight ranged from 800 grams to 3290 grams (mean= 1752 grams, stdev. = 510 grams) and weight at time of recording between 1270 grams and 2730 grams (mean= 2066 grams, stdev. = 381 grams).

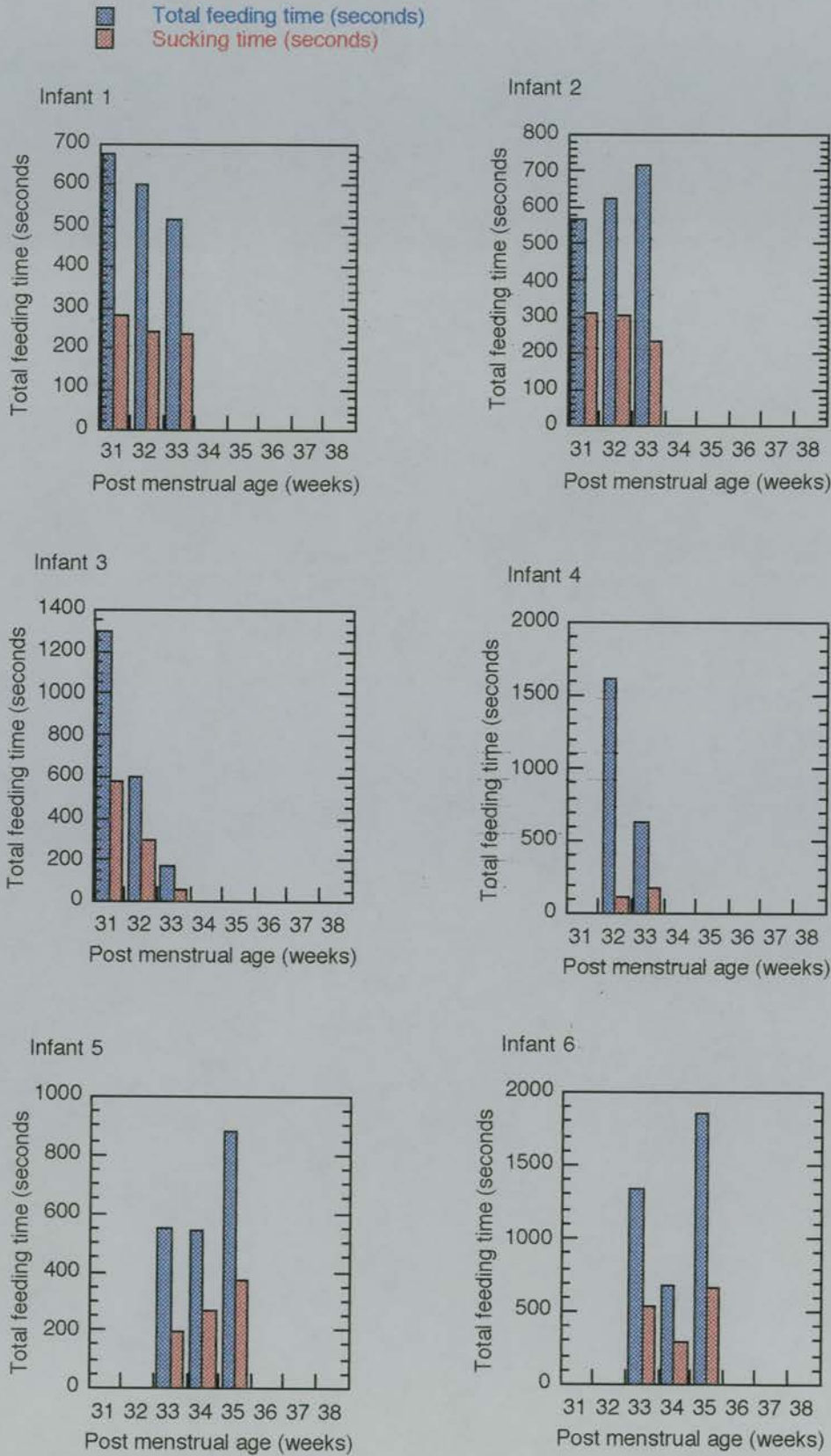
## **7.3    *Results***

### **7.3.1    *Components of feeding***

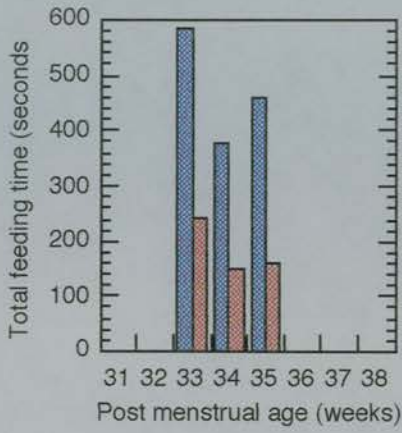
Some similarities and differences were noted among infants however the total number of infants in this study were insufficient to determine significance. Therefore the following discussion of the results refers to observed trends and not significant differences.

The following bar charts (figure 18, pages 146-149) illustrate the variability in overall feeding time and portion of feeding time which is taken up by sucking in 19 infants as they become increasingly more mature.

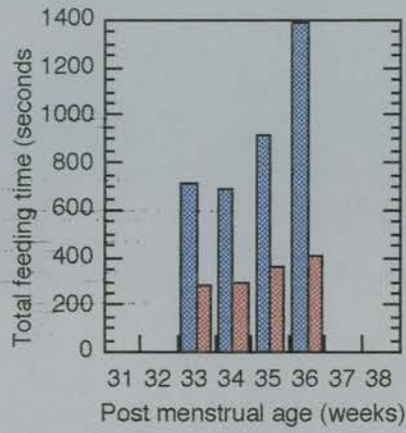
Figure 18    Longitudinal changes in feeding time and sucking time  
(seconds) for 19 individual infants of varying PMAs at time  
of testing



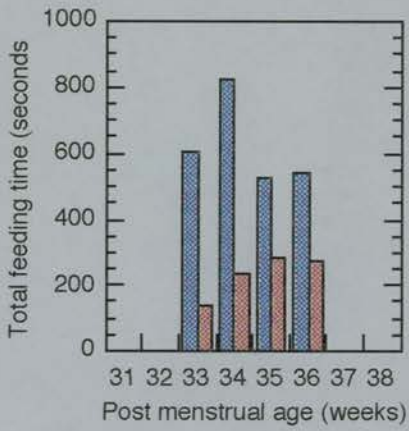
Infant 7



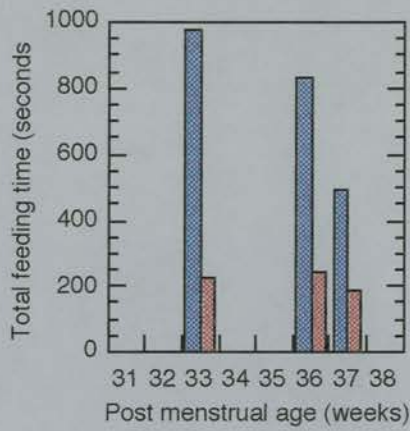
Infant 8



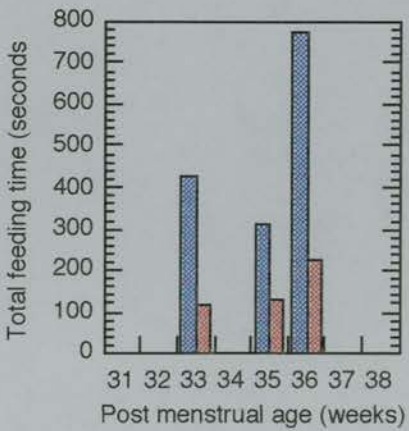
Infant 9



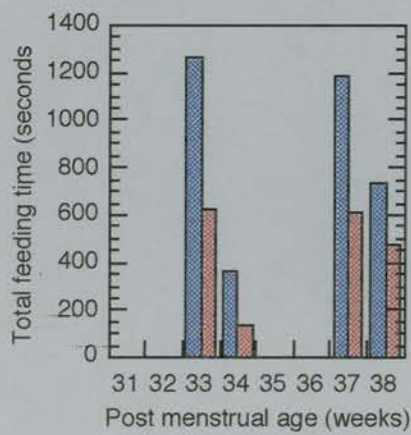
Infant 10



Infant 11

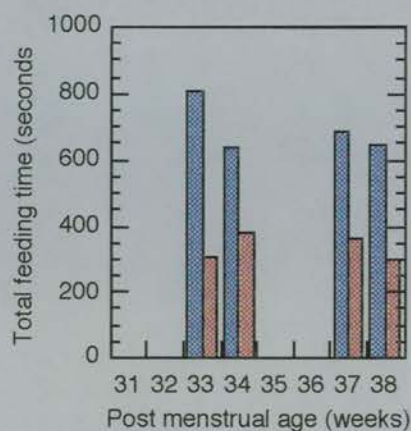


Infant 12

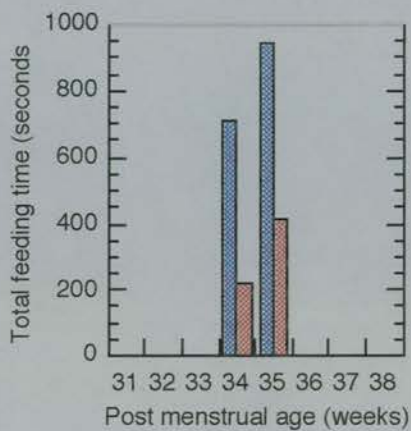




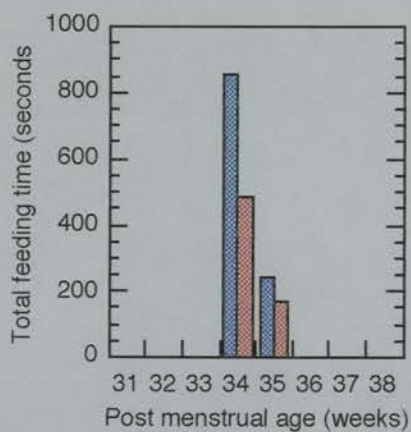
Infant 13



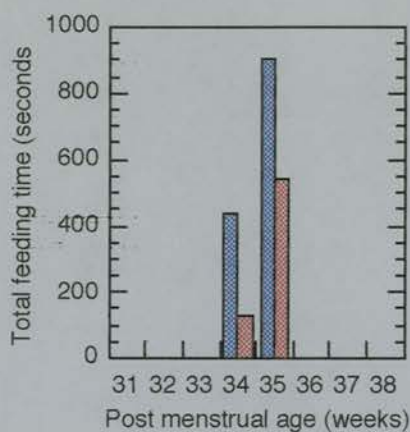
Infant 14



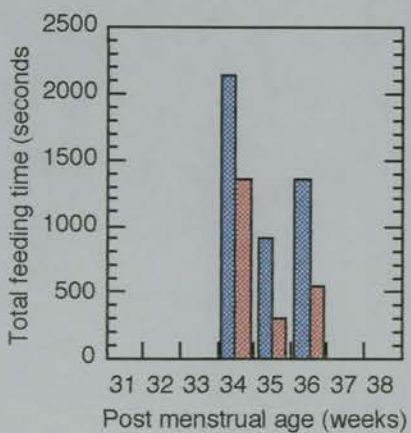
Infant 15



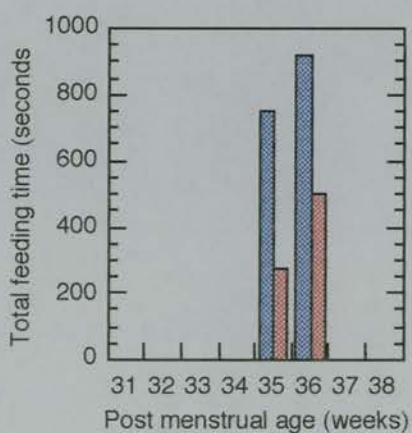
Infant 16

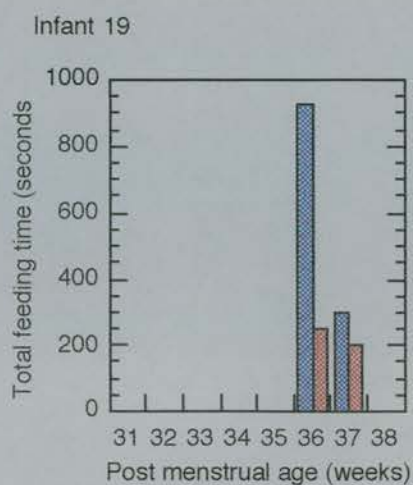


Infant 17



Infant 18





Although overall feeding time was variable, it was generally found that as infants matured their feeding times became shorter. The time spent in sucking was equally as variable but this was not unexpected because of the differences in total feeding time. However the proportion of time spent in sucking did not develop as expected.



PMA at time of feed	Individual infants numbered from 1 - 19																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
31	41	54	44																
32	40	48	47	7															
33	45	32	31	28	20	40	41	39	22	22	27	49	37						
34					48	43	40	41	28			36	59	30	56	29	62		
35					42	35	34	39	53		42			43	72	59	33	37	
36								29	50	29	28						39	53	26
37										38		51	52						67
38												65	46						

Table 14      % of total feeding time spent in sucking for individual infants (1-19) according to PMA (weeks) at time of test

Even with the variability in total feeding time it was expected that as infants matured they would spend proportionally more time in sucking and less in pause. However the data in table 14 illustrates that for many infants, with increasing PMA and thus maturity the proportion of time spent in sucking did not increase .

It was also anticipated that with maturity the duration of sucking bursts would increase. In some feeding records the proportion of total feeding time spent in sucking increased between first and last measurements and at the same time the number of sucking bursts decreased thus suggesting an overall increase in burst time (tables 14 & 15).

PMA at time of feed	Individual infants numbered from 1 - 19																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
31	39	34	57																
32	37	36	31	12															
33	30	33	11	42	21	94	21	61	18	26	14	83	41						
34					34	60	25	33	46			14	30	31	24	18	87		
35					72	99	15	52	27		16			38	12	31	31	16	
36								76	34	38	35						61	30	44
37										28		46	37						11
38												34	34						

Table 15     Number of sucking bursts for individual infants (1-19)  
                 according to PMA (weeks) at time of test

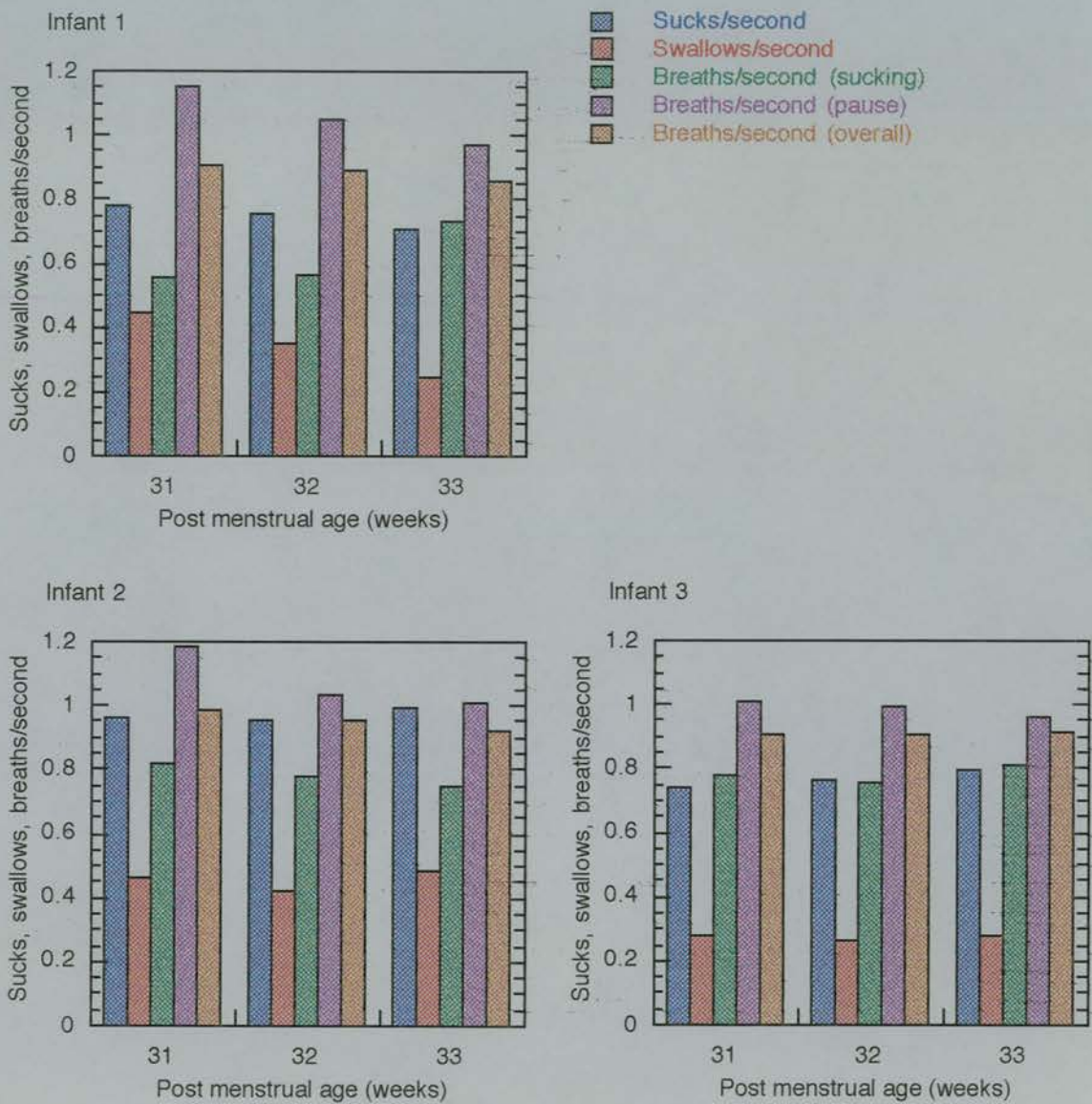
When comparing the feeding elements (per second) of sucking, swallowing and breathing during sucking, breathing during pause and breathing overall throughout feeding, patterns emerge for individual infants and sometimes but not often between infants (figure 19, pages 153-156).

Sucking frequency as expressed by mean sucks/second were always greater than swallowing frequency and generally greater than or equal to mean breaths/second during the sucking period. Sucking frequency was less than breathing frequency in only 3 records; these occurred in infants measured at 33 and 34 weeks PMA and did not appear to be related to milk flow as indicated by swallow frequency. Swallow frequency

remained variable irrespective of individual infant or PMA at time of testing.

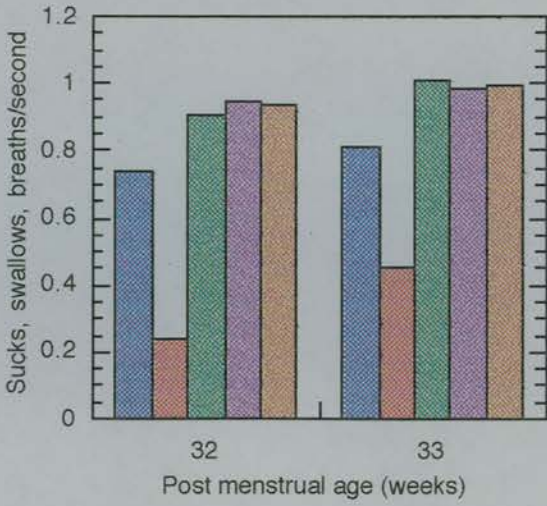
Mean breaths/second during pause were greater than or equal to the mean breathing frequency of overall feeding. As mean breathing frequency for overall feeding was maintained between 0.8 and 1.2 breaths/second, this would suggest that infants utilise pause periods to meet the changing ventilatory needs of sucking.

Figure 19    Longitudinal changes in mean sucks, swallows and breaths /second during sucking, mean breaths/second during pause and mean breaths/second throughout feeding for 19 infants of varying PMAs at time of testing

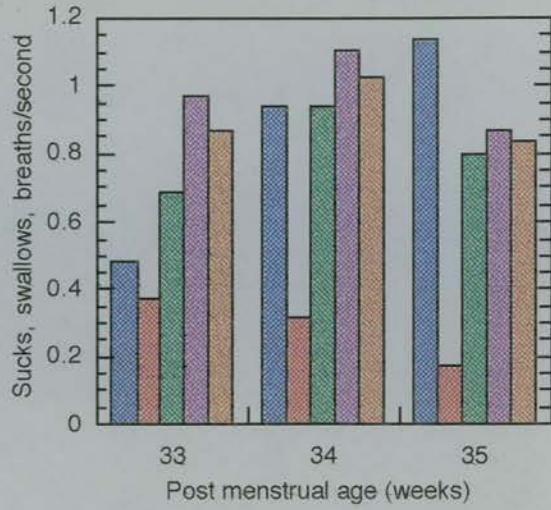




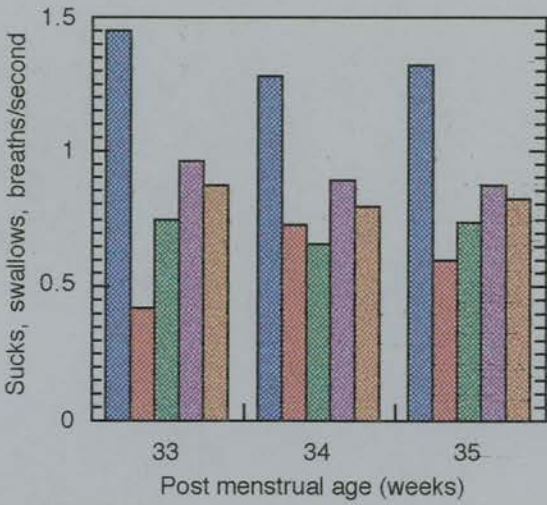
Infant 4



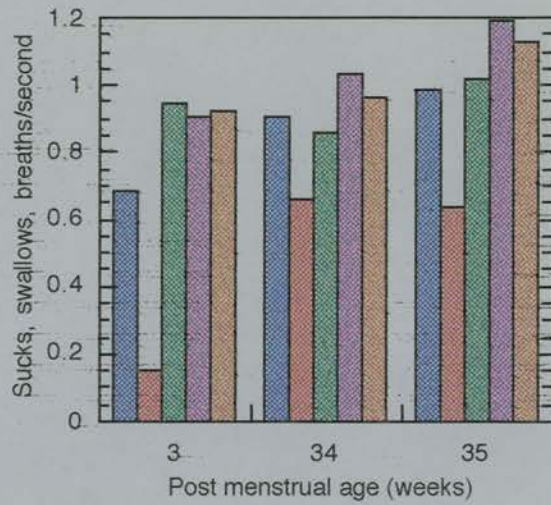
Infant 5



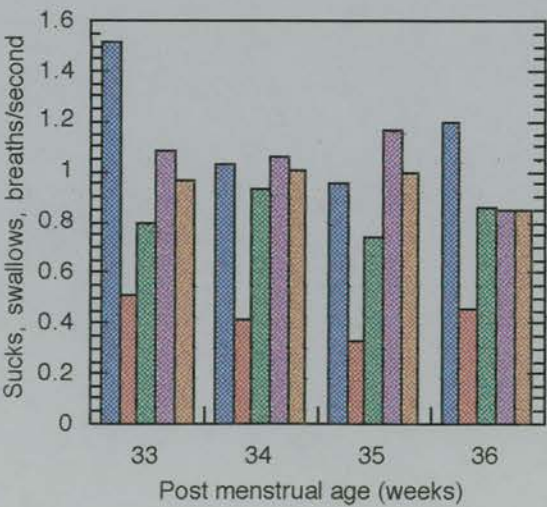
Infant 6



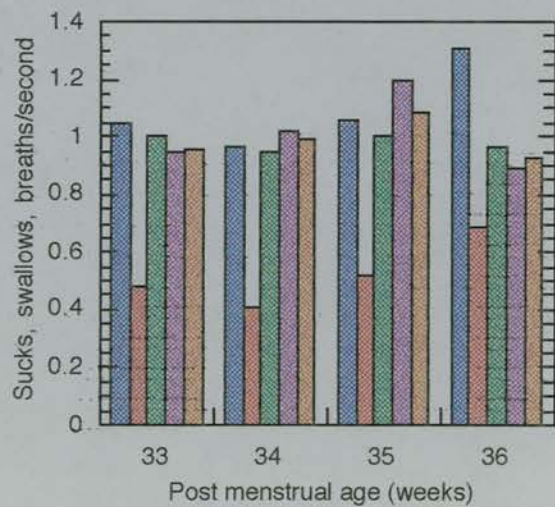
Infant 7



Infant 8

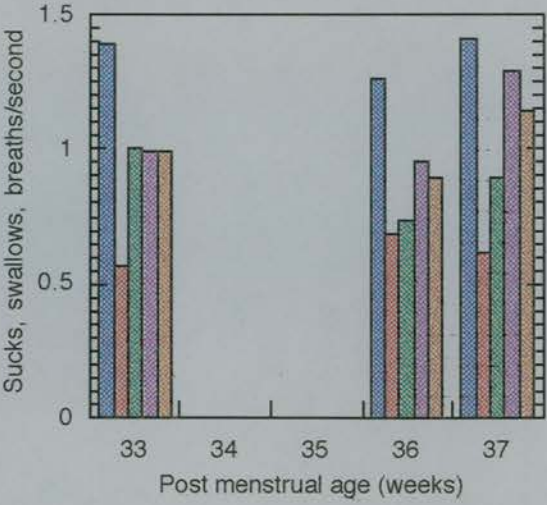


Infant 9

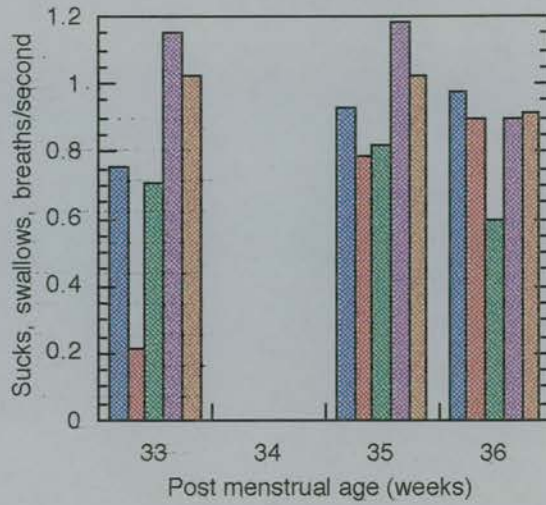




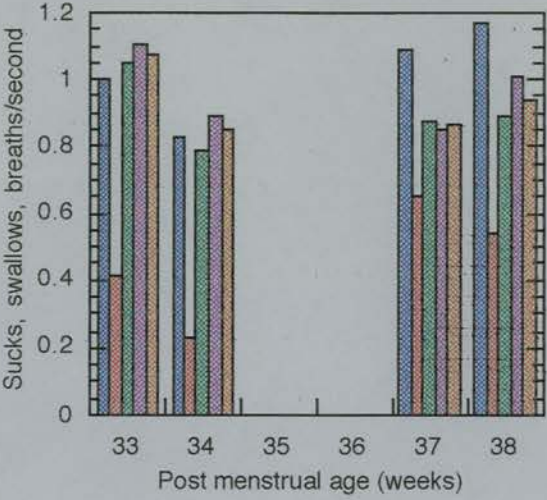
Infant 10



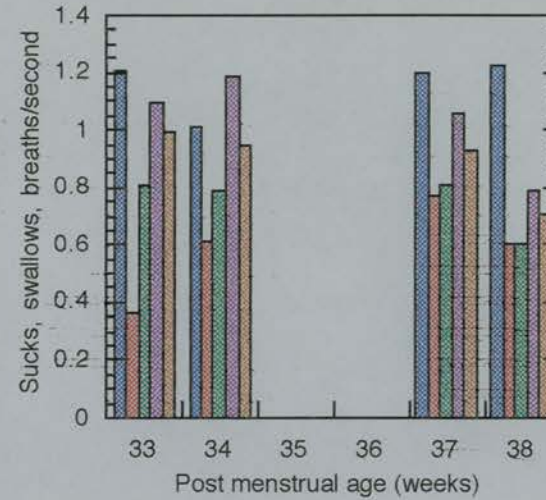
Infant 11



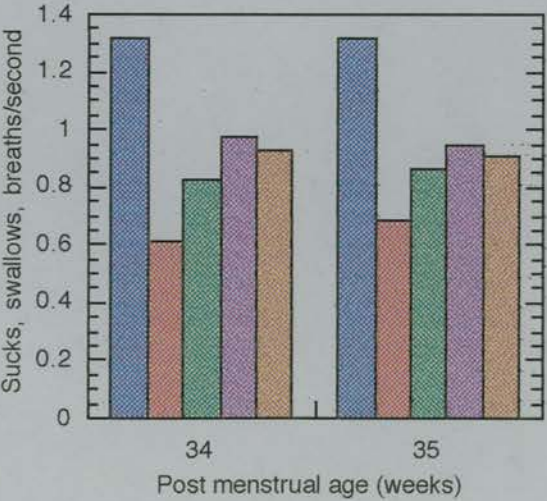
Infant 12



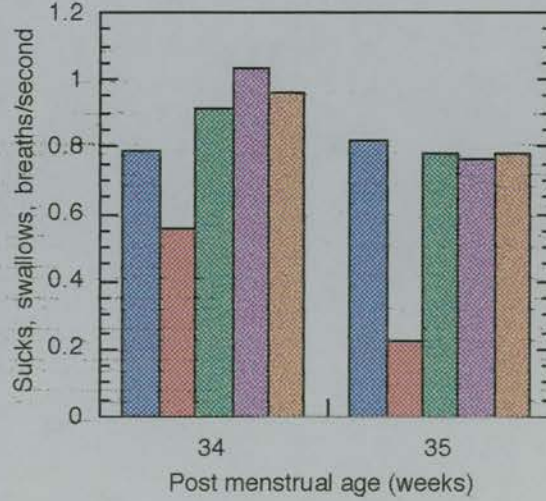
Infant 13

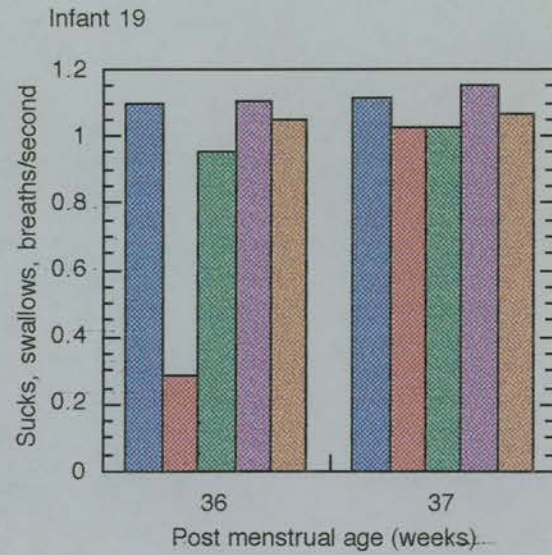
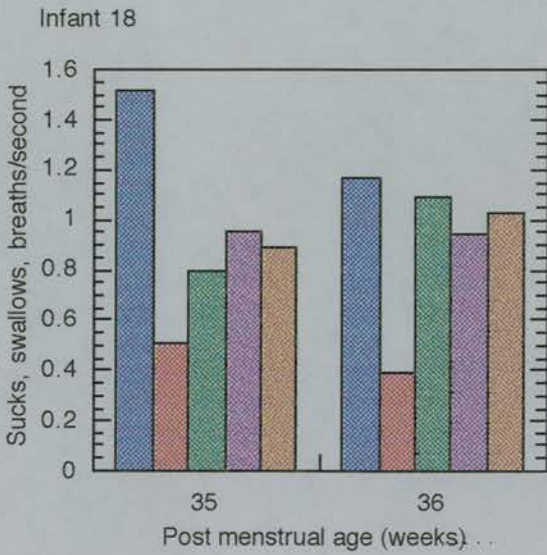
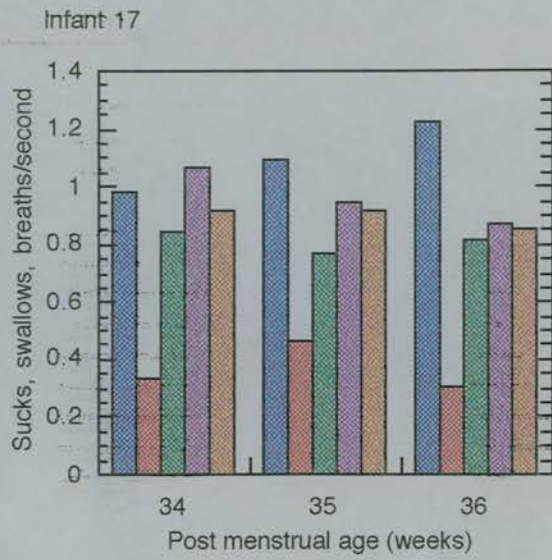
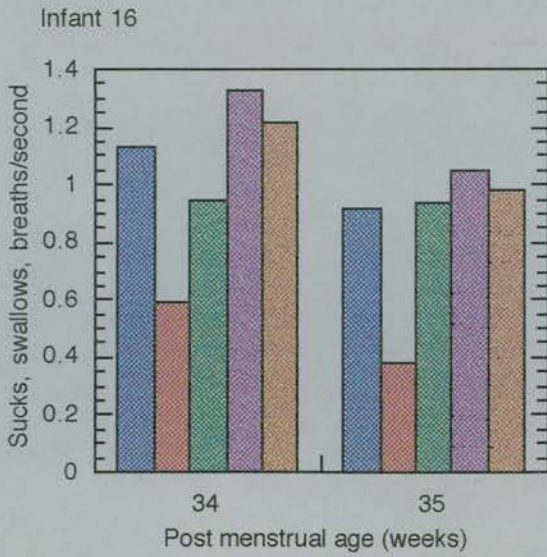


Infant 14



Infant 15





## 7.4 Discussion

The data in this small series represents preliminary work on the development of breast feeding in premature infants. Although some of the trends appear comparatively small, they may be of clinical importance and are therefore worth commenting on. One might speculate as to why different feeding patterns emerged. The following discussion describes



possible mechanisms individual infants utilise to regulate and support feeding.

The longitudinal changes observed in total feeding time were not as expected. It was anticipated that as infants matured they would become more robust and able to participate in the activity of feeding for longer albeit spending less time in pause (Dubignon, 1980). Meier (1985) describes longitudinal changes in her cohort of infants which support the notion of infants not only becoming more efficient at sucking but also more interested in their surroundings whilst feeding thus extending feeding times. In the current study the trend for overall feeding time was to be reduced as infants matured; in some infants sucking time as a proportion of total feeding time did not increase in a commensurate manner with increasing PMA.

Medoff-Cooper (1993) and Gryboski (1969) describe sucking frequency and swallowing respectively as increasing with post menstrual age. They suggest progressive organisation in neuromotor activity is accomplished with increasing maturation of the central nervous system. Efficiency is described as sucking bursts becoming longer and the number of sucks and swallows within each burst increasing. In the current study infants demonstrated various combinations of burst/pause length, sucks, swallows and breaths/second during sucking and breaths second during pause.

The tendency towards decreasing burst time may in part be due to compensatory mechanisms by which infants manipulate burst time to adjust frequency of sucking, swallowing and breathing. This may be the

case as illustrated by infants 2, 3 and 7. In these feed records infants decrease the proportion of time spent in sucking and the number of sucking bursts as they mature. Conversely they increase pause time and mean breaths/second during pause. These changes may be in response to the small to moderate increase in swallow frequency which might have brought about ventilatory compromise.

The feeding record of infant 1 shows an increase in sucking time and a decrease in burst number indicating an increase in burst time. This increase in sucking activity may be one method by which the infant attempts to increase milk flow (swallows/second were greatly reduced over the 3 weeks of testing). However although the infant increased his sucking activity he also reduced the frequency of sucks/second. Furthermore mean pause time was also decreased thereby limiting possible time for respiratory recovery. Infants 16 and 18 also demonstrated in their second measurements a reduced swallow frequency and this may have been the trigger for increasing sucking activity. However their mean sucks/second were also reduced. Timms (1993) showed that in the presence of CO<sub>2</sub> retention, sucking activity halted. Therefore these 3 infants may have incorporated a feedback system to increase sucking activity and thus nipple stimulation but to slow sucking frequency thereby enabling restitution in ventilation.

In conclusion the longitudinal changes seen in these infants may represent remarkable mechanisms whereby infants of varying PMA's adapt the activities of feeding to maintain physiological stability. Some parameters of feeding develop in a similar fashion to those reported by others:

Meier (1988) demonstrated with increasing PMA a trend towards longer bursts of sucking with increasing sucking frequency.

Sucking bursts were interrupted by lengthy periods of pause; Medoff-Coooper (1993) showed similar findings in bottle feeding infants; Mathew (1989) showed changes to breathing pattern as a consequence of milk flow. Similar changes are speculated in the current study .

There appears to be no real pattern as to development of feeding in breast feeding infants. The data presented in the current study highlights the characteristics of feeding as being unrelated to PMA or feeding experience but unique to the individual at a particular time.

## **CHAPTER 8**

# Chapter 8

## The "work" of oral feeding as expressed by changes in heart rate

### 8.1 *Introduction*

The primary goal of nursing the compromised infant is to support the infant during recovery whilst optimising growth and development. Any state or condition which increases the work of living from that of quiet rest requires an increase in energy (Brooke, 1979). The premature infant is poorly adapted to meet increasing requirements in energy; energy reserves are low, surface area to body mass large, fat distribution and muscle mass minimal. Together with general immaturity these factors make him prone to physiological stress. Stress responses, can present in the form of hypothermia, bradycardia and irregular or absent respirations. These may arise through poor nursing management or as a consequence of immaturity and illness. The effort taken in achieving stability and homeostasis often increases the energy requirements of the infant. Therefore activities which impinge on his reserves or require an increase in energy expenditure need to be evaluated.

#### 8.1.1 *Energy expenditure*

Energy expenditure may be measured by a number of techniques. Direct calorimetry measures oxygen consumption and heat production within a regulated environment whilst indirect calorimetry measures parameters

of growth during a period of time when exact measurements and thus energy content of nutritional intake and subsequent output are known.

A further method is by utilisation of double labelled water. Two stable isotopes in the form of water are administered to an infant. The subsequent difference between the disappearance rates of the two isotopes indicates the rate of carbon dioxide production and with an individual's respiratory quotient, an estimate of oxygen consumption and hence energy expenditure can be made.

Estimates of energy expenditure using these methods are time limited usually between a few hours and a number of days and as such may be restricting in the provision of care. Because of the time periods involved they do not take into account energy expended during specific activities.

A fourth method of estimating energy expenditure is by monitoring changes in heart rate. Alteration in heart rate may reflect changes in oxygen need and therefore indirectly energy expenditure. Chessex (1981) showed a tight relationship between heart rate, oxygen consumption and energy expenditure in individual infants using a method based on the Fick principle.

The Fick principle defines cardiac output as the ratio of oxygen consumption to the difference in oxygen content between arterial and venous blood. Since cardiac output is mostly influenced by changes in heart rate and not stroke volume the relationship defined provides a basis for estimating oxygen consumption from heart rate (Lees, 1967; Woodson, 1983). Regression equations calculated from simultaneous



measurements of heart rate and oxygen consumption give values of energy expenditure. Therefore one may predict changes in energy expenditure in individual babies by changes in heart rate. Factors which cause a change in level of arousal may also affect heart rate and therefore oxygen consumption (Cranston Anderson, 1990).

### **8.1.2 Behavioural states**

"State" and changes within, reflect an individual's alteration in level of consciousness (Brazelton, 1994). The stages of consciousness are grouped into behaviours between sleeping and waking. These may occur spontaneously or in response to external stimulation and are considered to represent an individual's level of receptiveness and central nervous system maturity.

Preterm infants are known to spend approximately 80-90% of time in sleeping (Holditch-Davies, 1990; High & Gorski; 1985, Stefanski, 1984). This may be divided into active and quiet sleep where predominantly (about 75%) active sleep occurs. Awake and transitional states account for the remainder where waking occurs approximately 8-12 % of time. As infants mature active sleep decreases and is replaced by quiet sleep, fuss and crying. Thus the proportion of active to quiet sleep alters as a result of maturation.

#### **8.1.2.1 State response to stimuli**

All caregiving requires some form of 'hands on' intervention, be it direct or indirect. This may take the form of painful procedures, basic nursing care, or interactional touch. One study, (Gottfried, 1985), found the

typical premature infant was disturbed by handling 82 times in a 24 hour period and that the nature of disturbance was task orientated care. Other studies report infants being handled between 11 and 23% of the day (Blackburn, 1989). Handling in whatever form disrupts the sleep-wake patterning of the infant, with the infant being unable to sustain quiet sleep during interventions or interactions (Oehler, 1988; Holditch-Davis, 1990). Gottfried (1985) suggests that stress signals elicited as a response to inappropriate interventions may occur as a result of change in the sleep-wake state. These changes may lead to disorganisation and poor development.

Several studies have focused on the physiological and behavioural effects of specific interventions or interactions (Norris, 1982, Field, 1984). Long (1980a) demonstrated the physiological effects of sleep disturbance through excessive handling. In this study, 75% of recorded hypoxia was as a consequence of handling. Other activities frequently associated with significant changes in heart and respiratory rate, intracranial pressure and circulating oxygen include chest physiotherapy and endotracheal suctioning, blood sampling from heel stabs, and basic care activities of feeding, nappy changing and repositioning (Peters, 1992; Danford, 1983; Wolke, 1987). It is difficult to know what acute or long term effects these interventions have on the infant but changes in cerebral perfusion and oxygenation are associated with periventricular haemorrhage and cell hypoxia with ischaemia and death.

These care activities may be necessary but greater consideration should be given to the timing and frequency of these interventions. Variation within each activity may improve the infant's ability to maintain stability

and homeostasis. When comparing modes of stimulation, Gorski (1990) found no difference in degree of bradycardia or hypoxia between painful interventions and gentle interactional touch. He concluded that timing of stimulation played an important role in maintaining stability. Other authors have found that appropriate interactional touch could improve behavioural state and developmental outcome as well as increasing weight gain in the premature infant (Barnard, 1983; White-Traut, 1993).

More specifically, looking at the effects of non-nutritive sucking, Bernbaum (1983) found similar positive effects as well as a swifter transition to bottle feeding and decreased length of hospitalisation. Calming effects were further demonstrated in a study examining heart and respiratory rate and percentage of time spent crying before, during and after heel stabs (Field, 1984). Study infants were allowed the opportunity to suck on a dummy during the procedure resulting in a lower heart and respiratory rate with less time fussing and crying.

Changes between and within states are also accompanied by changes in physiological functioning as represented by alteration and stability in cardiovascular, respiratory, gastro-intestinal, endocrine and renal performance (Orem, 1980). Of particular interest is that of cardiovascular functioning.

#### ***8.1.2.2 State and cardiac output***

Level of arousal has been found to affect cardiovascular functioning. Generally the heart rate is higher during waking than sleeping. Whilst asleep, there is more variability during the active rather than the quiet

phase (De Haan, 1977). The waking state of 'crying' is associated with increases in heart rate, cerebral blood flow and decreases in saturated oxygen levels (Huch, 1981; Brazy, 1988).

## **8.2    *Aim***

From personal observation and through discussions with neonatal caregivers, an assumption made by many is that oral feeding is tiring and at times stressful for premature infants and therefore should be limited in both opportunity and length of feeding. Opportunity for feeding is frequently arranged around parents visiting and unit guidelines with attention seldom placed on how ready the infant is to participate in the activity of feeding. The purpose of the present study therefore is to evaluate heart rate and behavioural state as indicators of energy expenditure or the "work" related to feeding during the preparation for and course of feeding .

## **8.3    *Method***

Data from 47 feed records were analysed to describe changes in heart rate. In addition to the physiological data, behavioural state changes [using Anderson Behavioural State Scale - table 2, appendix] were also noted between undisturbed rest, prior to feeding and between just finishing sucking and a period of rest. The physiological data were continuously collected as described in chapter 4 for a period of time prior to, during and post feed. Records were obtained from some infants on more than one occasion but there were at least 6 days between each

recording. Table 16 gives summary background information about the infants who were included in this analysis.

PMA at time of feed (weeks)		31	32	33	34	35	36	37
total no. of recordings		n=3	n=4	n=10	n=9	n=9	n=6	n=6
birth gestation (weeks)	mean	29	29	30.9	30.8	32	30.4	32
	stdev	0	0	.74	.83	1.8	1.4	2.8
birth weight (grams)	mean	1142	1169	1715.5	1696.7	1965.4	1531.7	1792.
	stdev	173.6	151.7	174.5	213.9	604.5	417.3	694.4
weight at feed (grams)	mean	1314	1518.3	1904.1	2101.1	2414.4	2446.3	2495
	stdev	120.4	159.8	185.1	269.9	418.2	221.9	230.3

Table 16      Summary data showing number of measurements according to PMA against mean birth gestation, birth weight and pre-feed weight

Irrespective of length of feeding, the continuous recording of heart rate during each monitoring session was divided into specified time segments. These segments were classified as pre-feeding, feeding and post-feeding. Pre-feeding was divided into 2 minutes of undisturbed rest followed by 6 minutes of handling and rest (for nappy change) and finally 2 minutes of pre-feed rest. Feeding was the aggregate of heart rate throughout the activity of feeding. Post-feeding was divided into the first 2 minutes after stopping sucking followed by 6 minutes of rest and finally 2 minutes of rest.

Statistical analyses was carried out on heart rate and behavioural state data using analysis of variance, Spearman correlation coefficient and Wilcoxon signed ranks where appropriate.

8.4 Results

8.4.1 Heart rate and feeding

Analysis of variance was conducted on mean heart rate (HR) initially over 5 time epochs to assess reaction to varying stimuli. The 5 intervals being as described previously as 2 minutes each of 'undisturbed' and 'pre-feed' rest, the aggregate of feeding and 2 minutes each of 'post-feed' rest and 'resting' (table 17).

Activity	Undisturbed	Pre-feed	Feeding	Post-feed	
	Resting				
mean HR	154.95	160.15	158.02	154.66	152.53
stdev	12.61	10.27	8.5	9.81	9.94

Table 17      Mean and standard deviation values for heart rate in 47 subjects during activities surrounding feeding.

Analysis of variance indicated that that there were significant differences between the five epochs, Scheffé F-test (4, 184) 8.653, p =0.001.



The differences were between:

undisturbed and pre-feed H.R.,	$F = 3.23 \text{ } p = < 0.05;$
pre-feed and feeding H.R.,	$F = 0.542 \text{ NS};$
pre-feed and post feed H.R.,	$F = 3.596 \text{ } p = < 0.01;$
pre-feed and resting H.R.,	$F = 6.937 \text{ } p = < 0.01 \text{ and}$
feeding and resting H.R.,	$F = 3.601 \text{ } p = < 0.01.$

Although the mean heart rate was less during feeding than the pre-feed epoch, no significant difference was seen between pre-feed and feeding. The data were therefore subject to further analysis. Each feed was individually subdivided into the first 2 minutes of feeding (first), middle 2 minutes of feeding (second) and last 2 minutes of feeding (third). The assumption being that infants would vigorously suck at the beginning of feeding as this would be the time of greatest hunger. Therefore heart rate would be higher at this time than at any other. As feeding progresses and pausing occurs, infants spend more time in rest and are therefore more likely to show a decrease in heart rate in the later stages of feeding. The mean heart rates for pre- and post-feeding and the three interval of feeding are shown in table 18.

Activity	Pre-feed	First	Second	Third	Post-feed
mean HR	160.15	159.79	157.08	157.34	154.66
stdev	10.27	10.16	10.06	9.6	9.81

Table 18      Mean and standard deviation values for heart rate in 47 subjects during feeding.

Using analysis of variance, no significant differences in heart rate were seen between three divisions of feeding, Scheffé F-test (2, 92), 2.92 p = NS.

When considering pre- and post-feeding heart rates significance was only seen between the:

first 2 minutes of sucking and the post-feed period;

$$F = (4, 184), 3.699 \quad p = 0.01;$$

pre-feed and first 2 minutes of feeding

$$F = (4, 184), 0.19 \quad \text{NS};$$

first 2 minutes of feeding and middle 2 minutes of feeding

$$F = (4, 184), 1.035 \quad \text{NS};$$

middle 2 minutes of feeding and last 2 minutes of feeding

$$F = (4, 184), 0.01 \quad \text{NS and}$$

last 2 minutes of feeding and first 2 minutes of rest

$$F = (4, 184), 1.01 \quad \text{NS}.$$

No relationship was found between heart rate and the specific activity of feeding. The analysis of variance on feeding heart rate indicated that with sucking no significant changes occurred. However pre-feed handling, of position and nappy change, did significantly alter heart rate. This influence continued into the first interval of sucking as no difference was seen between pre-feed and first two minutes of sucking. The difference seen between the first two minutes of feeding and post-feed rest was not unexpected because of the similarity between pre-feed and the first two minutes of sucking.

It may be that changes in behavioural state arising from 'handling' account for the changes seen in heart rate.

8.4.2 Heart rate and behavioural state

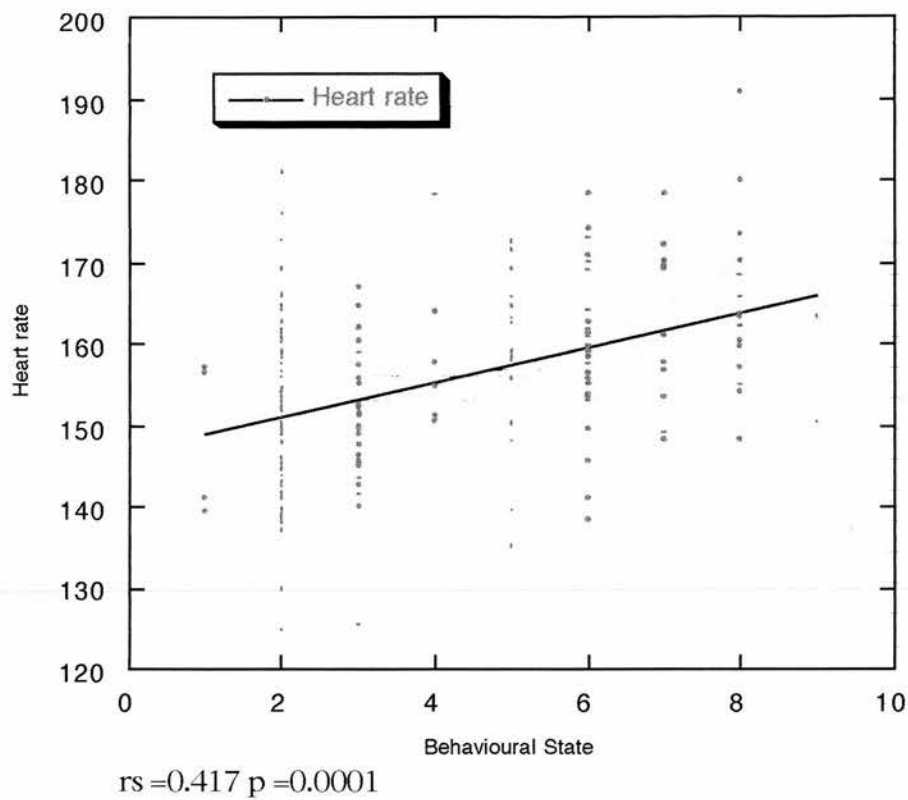


Figure 20 188 events of mean heart rate plotted against behavioural state

Figure 20 illustrates the association between heart rate and behavioural state. Using Spearman's correlation coefficient, the association indicates a significance of  $p = 0.0001$ ,  $df = 186$ ,  $r_s = 0.417$ . The mean of mean heart rates for individual behavioural states are shown in table 19.

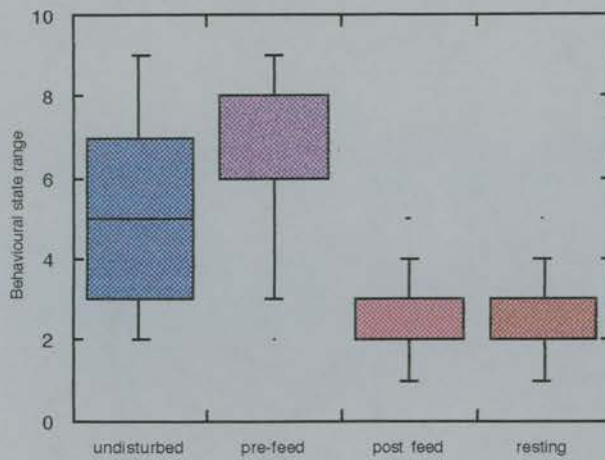
<b>A.B.S.S.</b>	1	2	3	4	5	6	7	8	9
<b>(frequency)</b>	(4)	(67)	(34)	(6)	(16)	(30)	(12)	(17)	(2)
<b>HR</b>	148.61	151.62	151.39	159.53	158.33	159.71	163.08	164.42	156.9
<b>(stdev)</b>	9.62	10.85	8.47	10.46	10.62	9.33	9.87	10.3	9.13

Table 19      Mean of mean and standard deviation values for heart rate  
for each behavioural state using Anderson Behavioural  
State Scale [A.B.S.S. - table 2, appendix]

Thus where there is a change in behavioural state towards waking and restlessness (from 1, asleep, to 12, crying) an increase in heart rate is also seen. When grouping the states into sleeping, awake and restless the proportion between the 4 activity intervals are:

Undisturbed	sleeping 57.4%	awake 29.8%	restless 12.8%
Pre-feed	sleeping 14.9%	awake 57.4%	restless 12.7%
Post-feed	sleeping 100%		
Resting	sleeping 100%		

It can also be seen from figure 21 that behavioural state alters significantly between undisturbed, pre-feed resting and post-feed resting intervals (Friedmans  $\chi^2$  79.372, df 3, p <0.0001). No data on behavioural state could be collected during feeding as the researcher was at this time collecting data on the various elements of feeding.



*Figure 21* Range and quartiles of behavioural state according to predefined time interval. [Box plots represent 75% of values with bars indicating maximum and minimum values for each activity interval].

When using Wilcoxon matched pairs signed ranks, the significant differences were only between undisturbed and pre-feed behavioural states ( $z = -3.809$ ,  $p < 0.0001$ ) and pre-feed and post-feed behavioural states ( $z = -5.883$ ,  $p < 0.0001$ ). No significant difference was noted between the two post feed resting periods.

Thus it can be seen that the change in behavioural state from undisturbed to pre-feed resting contributed to the increase in heart rate between these two intervals. In addition the care activities surrounding and including feeding brought about a significant alteration in behavioural state and heart rate.

## 8.5 *Discussion*

The data presented here suggests that the activity of oral feeding does not cause an increase in heart rate. Rather it is the activity or change in behavioural state pre-feed which causes the increase (Long, 1980; Medoff-Cooper, 1993). Subsequent oral feeding appears to calm the infant and thus lowers the heart rate. It may be argued that the activity of sucking was not responsible for the resolution in behavioural state or heart rate to undisturbed pre-feed levels; these changes may have resulted from swaddling and cradling the infant. However McCain (1992) examined the effects of several interventions on heart rate and behavioural state in premature infants. In this study, infants in the control group, who were held in the researcher's lap, were compared against three intervention groups which consisted of infants being held but also receiving non-nutritive sucking, non-nutritive sucking with rocking or only stroking. Non-nutritive sucking alone showed the greatest effect in changing behaviour to inactive awake and in reducing heart rate. It may be inferred therefore that in the current study the intervention of comforting on its own was not the prime cause for altering heart rate or behavioural state but rather the activity of sucking brought about the change.

The activity of oral feeding in the current study is seen to alter the behavioural state from that of wakefulness to sleeping. These findings are similar to those observed in studies on non-nutritive sucking. Non-nutritive sucking prior to and during gavage feeding has been demonstrated to modulate active awake and fussiness into quiet awake and sleeping (Field, 1984; Anderson, 1990; McCain, 1992; DiPietro, 1994). Following gavage feeding, DiPietro (1994) found infants who had been



given the non-nutritive sucking opportunities during feeding settled more quickly and therefore spent less time awake or fussing. It is not surprising therefore that with oral feeding, the proportion of waking and restlessness should diminish over the course of feeding.

The changes in heart rate in response to altered behavioural state were also not unexpected. Woodson (1988) and Anderson (1990) demonstrated similar findings in heart rate/behavioural state association as were found in the current study. The lowest mean heart rate was found during regular quiet sleep and the highest during the active awake state. The mean heart rate for the very active awake state was low when compared to the other awake states but this may be due to the state occurring infrequently (table 19). Generally heart rate increased with activity and wakefulness.

However these findings are in contrast to those of Ludington (1990) and DiPietro (1994) who showed that interventions, of skin-to-skin care and non-nutritive sucking during gavage feeding respectively, had positive effects on behavioural state, that is to reduce the frequency of state changes and bring the infant to quiet alert, but not significantly alter physiological parameters. The lack of lowering heart rate with skin-to-skin care in the presence of less activity and increasing quietness may have resulted from an increase in central temperature. The heart rate findings of DiPietro (1994) are similar to those of Symon (1994) who showed little change in heart rate with gavage feeding. It may be that the volume of milk and speed at which it was administered during gavage feeding affected the vagal response and thus heart rate.

Energy expenditure has been demonstrated to alter according to behavioural state and heart rate. The findings of Brooke (1979) indicated that energy expenditure increased with activity, between 23 and 34% above resting levels. Least energy expenditure was noted during sleeping and most during crying, the two extremes of behavioural arousal. A similar change in energy expenditure was shown by Masterson (1987). In this study of low birth weight infants, a position change from supine to prone increased the amount of quiet sleep and decreased the amount of waking that infants experienced. The behavioural changes were significantly associated with changes in energy expenditure.

In studies utilising the Fick Principle of heart rate and oxygen consumption as indicators of energy expenditure (Chessex, 1981; Woodson, 1983) it was shown that where there was an increase in heart rate there was a concomitant increase in energy expenditure. This was more recently supported by Butte (1992) who examined the differences in energy expenditure between breast and formula feeding infants. In her study it was found that heart rate responded to changes in behavioural state and through indirect calorimetry both were associated with energy expenditure.

In conclusion it may be inferred from these studies on behavioural state, heart rate and energy expenditure that in the current study, no more energy was utilised with feeding than in the immediate pre-feed period. The spontaneous or pre-empted waking by position and nappy change altered infants' level of arousal and it was this time, of increased activity, that energy expenditure was at its greatest. The activity of oral feeding demonstrated a calming effect which settled infants into sleeping and

thus lowered heart rate. Clearly the timing of interventions plays an important part in the physiological outcomes experienced by the infant (Gorski, 1990).

Therefore the assumption that oral feeding is a tiring activity, implying an increased work load on the part of the infant, is not supported by the data presented in this study. This is an important consideration when planning, with parents, a programme of feeding progression for their infant. Not only should caregivers encourage mothers to frequently breast feed their infants but also look to their own beliefs and practice. Contingency based care, that is care according to infant readiness rather than schedule, might be an alternative way of supporting feeding development.

## **CHAPTER 9**

# Chapter 9

## Conclusions

### *9.1 Conclusions*

The theoretical model governing this research implies a species-specific agenda for managing internal and external influences and for progressing along a developmental continuum. Als (1982) suggests physiological stability is essential before infants are able successfully to engage in purposeful motor activity. With increasing stability and control infants modify sleeping and waking and knowingly seek out environmental interaction. This current study has demonstrated the interplay of this subsystem functioning through the emerging ability of premature infants to successfully breast feed.

Meier (1990) in discussing her work describes the differences in feeding measurement outcomes of preterm infants during breast and bottle feeding. She suggests bottle feeding is a skill which is acquired later than breast feeding in the developmental programme of preterm infants. These studies indicate physiological instability when bottle feeding is first attempted but not during breast feeding. With increasing post menstrual age, improved motor control and stability leads to rhythmical, efficient feeding, and physiological compromise is not an issue.

The results of the current study show similar developmental changes in the acquisition of breast feeding skills. The most immature of infants

(those <30 weeks PMA) were able to suckle in a burst/pause pattern. They acquired milk and managed to coordinate breathing and swallowing without great compromise in respiratory or heart rate. It must be noted that although breathing frequency in these infants did not substantially reduce overall, two of the three infants required facial oxygen during the first few minutes of feeding. One inference may be that the depth of breathing was affected by sucking and swallowing but not the frequency. Facial oxygen was withdrawn once infants had established a burst/pause pattern and physiological compromise was not detected at any other time. However pre and post feeding respiratory rates have not been analysed and it may be that breathing during feeding was far less than during non feeding periods.

With increasing post menstrual age and thus maturity, infants altered their pattern of feeding. Total feeding time was reduced and this was quite unexpected. The proportion of sucking and pausing did not develop as anticipated. It was assumed that immature infants would feed for short periods of time and that mature infants would feed for longer, spending less time in pause; these being the characteristics of mature, organised feeding. However the data of the current study indicates other feeding patterns occur and suggests possible differences between breast and bottle feeding techniques.

The longitudinal data shows total feeding time to decrease and the proportion of sucking to pausing increase in some but not all groups. Measurements of mean burst time and number of sucks and swallows within bursts generally increase, with pause periods remaining lengthy irrespective of age, from less mature to more mature infants.

Throughout the text a number of suggestions have been given to try to explain the various combinations of feeding components and elements which infants employ to maintain stability and encourage progression. It is assumed that the strategies adopted are utilised to control milk flow and promote stability. They include: limiting burst time, altering the frequency of sucking, swallowing and breathing during sucking; incorporating non-nutritive sucking into feeding and by altering pause time and breathing frequency during pause. Although not measured in this study infants might also alter sucking pressure to influence milk flow. These are approaches which bottle feeding infants may to some extent take up but another suggestion as to why breast feeding infants manage feeding earlier with less compromise is offered by way of their feeding position.

The oro-pharyngeal anatomy of newborn human infants and their adult counterparts differs significantly, but it is remarkably similar to our primate ancestors. In animals the hyoid and larynx sit high within the oro-naso pharyngeal/ laryngeal area and a seal extends between the soft palate and epiglottis. There is also an intermediate seal between the posterior tongue and junction of soft and hard palate. The close proximity and subsequent movement of these structures allows an oral seal to be achieved during sucking but with some milk escaping to collect in the valleculae. On swallowing the soft palate elevates, the pharyngeal muscles contract, the hyoid ascends and the epiglottis tilts backwards. Thus the airway is protected as the milk flows into the oesophagus. Studies using anaesthetised or decerebrate animals have shown swallowing, in many species, to occur in the early inspiratory phase of



respiration (Bosma and Doty, 1956). In these cases the animals were laying in a horizontal position and swallowing was artificially triggered. It may be that newborn infants with their similar oral/pharyngeal anatomy, collect small amounts of milk during breast feeding in the valleculae. When this reaches some predetermined level, infants commence swallowing in a similar manner to other animals, that being in the early inspiratory phase of respiration.

At term infants are biologically programmed to receive, for the first few days of life, low milk volumes in the form of colostrum. It may be that these early days of feeding are practice days whereby infants master the techniques of feeding without the undue pressure of fast milk flow. Once lactation has been established infants use burst length, pause and sucking pressure to influence flow. In addition the semi-horizontal position used for breast feeding may allow milk to collect in the vallecula until sufficient quantity initiates swallowing. The inference being that bottle feeding, although in Scotland the predominant feeding method, remains artificial; milk flow may be more difficult to regulate and therefore techniques used to master the process prove complex and possibly abnormal for the preterm infant. Therefore the data from bottle feeding studies on the progress of feeding may not be reflective of normal development.

## ***9.2 Limitations of the study***

### ***9.2.1 Subjects***

One of the most important limitations of the current study is the lack of longitudinal data from all infants. The wide standard deviation and error values indicate the individuality of feeding and therefore longitudinal measures would have taken account of this and given a clearer picture of feeding development. Another aspect which was not discussed was the emergence of smooth sleep-wake patterns. On several occasions infants did not waken for feeding as expected and therefore data was not collected at these times. This selection of what constituted acceptable data for analysis may have biased the results. The small number of infants measured at various post menstrual ages also limits meaningful statistical inference and therefore the data must be interpreted with caution.

### ***9.2.2 Equipment***

Designing equipment appropriate for collecting this type of data proved difficult. It needed to be readily available, non-invasive and approved by Health and Safety regulations. In the current study, identification of sucking was dependent upon the correct positioning of the chin sensor and swallowing by interpretation and recognition of sounds by the researcher. These methods proved suitable and acceptable to both parents and infant but critical appraisal might suggest they introduce a level of bias and inaccuracy. However every effort was made through practice, prior to commencing the study, to achieve reliability.

Furthermore the techniques were tested against methods used in bottle feeding studies i.e. sucking pressures and microphone (Medoff-Cooper, 1991; Selley, 1990).

### ***9.2.3 Role of the researcher***

The role of the researcher in this study was not only to collect and collate data but also to advise, support and encourage mothers in commencing and maintaining lactation. In addition practical support was given in holding and positioning baby at the breast. Mothers and staff also consulted with the researcher as to how to progress with individual feeding plans. This extra help may have altered infant feeding performance and therefore inadvertently influenced the outcome measures. Nevertheless this additional involvement on the part of the researcher instilled confidence in parents to participate and supported data collection during a very personal and private activity.

### ***9.3 Further research***

Few studies have been conducted with premature infants during breast feeding. Having completed the current study, it is understandable as to why this might be. In collecting this data, compliance was essential not only from staff on the neonatal unit but also from mothers and infants. In addition mothers required an enormous amount of support which was time consuming. The data collection and analysis were difficult especially with the lack of validated equipment and techniques. One might consider these reasons to be influential in the dearth of reported data. However these difficulties did offer opportunities for developing other techniques,

thus broadening the base for methods of data collection in breast feeding preterm infants.

The results of the current study indicate further work is needed in this area. In particular, the notion of breathing phase and swallow timing as important determinants of physiological stability is intriguing. Another aspect which is of interest is how milk volume and flow are related.

#### ***9.4 Implications for clinical practice***

The findings of the current study have demonstrated the individual nature of infant feeding but some similarities were also seen. All infants irrespective of PMA were able to achieve coordinated swallowing with sucking and breathing. At no time were there any suggestions of milk aspiration or severe compromise. Indeed infants appeared to "enjoy" the event and the reduction in heart rate would suggest they were not overly taxed or stressed by the experience. Thus in terms of clinical practice infants of 31 weeks or greater in PMA who are demonstrating signs of feeding readiness ought to be allowed to suckle at the breast; however observations of milk flow, respiratory rate and oxygen saturation should be made in the less mature infants. Direct energy expenditure could not be measured but by inference from changes in heart rate feeding time need not be restricted as infants lowered their heart rate whilst feeding. Of importance however is the caveat that this only applies to infants who are looking to feed and therefore infants who are sleeping should not be disturbed.

Caregivers of the neonatal unit in which the current study was carried out have altered their practice in response to a change in knowledge base and the findings of the study. All mothers who chose to breast feed are encouraged to carry out skin-to-skin care and infant suckling, when their infant is medically stable, at the earliest opportunity. Mothers and caregivers are shown how to observe sucking and swallowing patterns and interpret feeding ability and success from these behaviours. Infants are not expected to behave in a similar manner because they have similar post menstrual ages. For example infants born at a gestational age of 28 weeks but who are 6 weeks old will not feed in the same way as infants born at 34 weeks gestational age and just starting to feed. Experience is a factor in feeding accomplishment and must be considered when assessing feeding.

Supplementary feeds are given according to individual infant feeding ability, growth pattern and maternal lactation. Generally, well preterm infants of less than 34 weeks PMA receive additional breast/formula milk via a gastric tube after breast feeding. Infants of 34 to 35 weeks PMA whose mothers have a good lactation are not given extra milk after breast feeding and those of greater than 35 weeks PMA are frequently allowed to demand feed.

This study has indicated a need for caregivers to reflect on their feeding guidelines and appraise the appropriateness to both infant and mother and further look at ways of assessing feeding competence in the anticipation of starting demand feeding at earlier times.

## **REFERENCES**

## References

- Al-Sayed L. E., Schrank W. I., Thach B. T. (1994) Ventilatory sparing strategies and swallowing pattern during bottle feeding in human infants  
*Journal of Applied Physiology* 77 (1) : 78-83.
- Als H. (1982) Toward a synactive theory of development: Promise for the assessment and support of infant individuality  
*Infant Mental Health Journal* 3 (4) : 229-243.
- Als H. (1983) Infant Individuality: Assessing Patterns of Very Early Development  
*In J. Call, E. Galenson, R.L. Tyson (Eds.) Frontiers of Infant Psychiatry. Basic Books, New York.*
- Als H. (1986) A Synactive Model of Neonatal Behavioural Organisation: Framework for the Assessment of Neurobehavioural Development in the Premature and for Support of Infants and Parents in the Neonatal Intensive Care Environment  
*Journal of Physical and Occupational Therapy in Pediatrics* 6 (3) : 3-55.
- Als H., Duffy F. H., McAnulty G. B., Badian N. (1989) Continuity of Neurobehavioral Functioning in Preterm and Full-term Newborns  
*In. M. Bornstein, N Krasnegor (Eds.) Stability and Continuity in Mental Development. Earlbaum, Hillsdale.*
- Anders T. F., Keener M. (1985) Developmental course of nighttime sleep-wake patterns in full-term and premature infants  
*Sleep* 8 : 173-192.
- Anderson J., Auster-Leibhaber J. (1984) Developmental therapy in the neonatal intensive care unit  
*Journal of Physical and Occupational Therapy in Pediatrics* 4 (1) : 89-106.
- Ardran G. M., Kemp F. H., Lind J. (1958) A cineradiographic study of bottle feeding  
*British Journal of Radiology* 31 : 11-22.
- Avery G. B., Glass P. (1989) The gentle nursery: developmental interventions in the NICU  
*Journal of Perinatology* 9(2) : 204-206.



- Baille L. (1995) Ethnography and nursing research: a critical appraisal.  
*Nurse Research* 3 (2) : 5-21.
- Bamford O., Taciak V., Gewolb I. H. (1992) The Relationship between Rhythmic Swallowing and Breathing during Suckle Feeding in Term Neonates  
*Pediatric Research* 31 (6) : 619-624.
- Barb S. A., Lemons P. (1989) The Premature Infant: Toward Improving Neurodevelopmental Outcome.  
*Neonatal Network* 7(6) : 7-15.
- Barnard K., Bee H. (1983) The impact of temporally patterned stimulation on the development of preterm infants  
*Child Development* 54 : 1156-1167.
- Becker P. T., Grunwald P. C., Moorman J., Stuhr S. (1991) Outcomes of developmentally supportive nursing care for very low birth weight infants  
*Nursing Research* 40 : 150-155.
- Bedi K. S., Warren M. A. (1988) Effects of nutrition on cortical development *In A. Peters, E.G. Jones (Eds.) Cerebral Cortex, Vol 7 : Development and Maturation of Cerebral Cortex* Plenum Press. New York.
- Behrman R. E., Gottoff S. P., Kliegman R. M. (1992) The fetus and the neonatal infant *In R.E. Behrman (Ed.) Nelson Textbook of Medicine (14th Edition), W.B. Saunders, Philadelphia.*
- Bennett F. C. (1987) The effectiveness of early intervention for infants at increased biological risk *In M. J. Guralnick, F.C. Bennett (Eds.) Effectiveness of early intervention for at risk and handicapped children* Academic Press, San Diego.
- Benton D. F. (1995) Grounded Theory.  
*In D.F.S. Cormack (Ed.) The research process in nursing (2nd Edition) Blackwell Scientific Publication, Oxford.*
- Bernbaum J. C., Periera G. R., Watkins J. B., Peckham E. J. (1983) Non-nutritive sucking during gavage feeding enhances growth and maturation in premature infants.  
*Pediatrics* 71 : 41-45

- Biber P., Creger P. J., Kolar D. (1989) Neurodevelopmental Assessment of feeding Abilities and Follow-up of the Disorganised Feeder  
*In P.J. Creger (Ed.) Developmental Interventions for Preterm and High-Risk Infants Therapy Skill Builders, Tucson.*
- Black J. E., Greenough W. T. (1986) Induction of pattern in neural structure by experience: Implications for cognitive development  
*In M. E. Lamb, A. L. Brown, B. Rogoff (Eds.) Advances in Developmental Psychology Erlbaum, Hillsdale.*
- Blackburn S., Barnard K. E. (1985) Analysis of caregiving events in preterm infants in the special care unit  
*In A. W. Gottfried, J. L. Gaiter (Eds.) Infant stress under intensive care: Environmental Neonatology University Park Press, Baltimore.*
- Blackburn S. T., VandenBerg K. (1989) Assessment and Management of Neonatal Neurobehavioral Development  
*In C. Kenner, A. Bruggemeyer, L.P. Gunderson (Eds.) Comprehensive Neonatal Nursing W.B. Saunders, Philadelphia.*
- Blaymore Bier J. A., Ferguson A., Anderson L., Solomon E., Voltas C., Oh W. (1993) Breast-feeding of very low birth weight infants  
*Journal of Pediatrics* 123 (5) : 773-778.
- Bosma J. F. (1972) Form and function of the infants mouth and pharynx  
*In J.F. Bosma (Ed.) Third symposium on oral sensation and perception C.C. Thomas, Springfield.*
- Bosma J. F. (1988) Functional anatomy of the upper airway during development  
*In O. P. Mathew, G. Sant'Ambrogio (Eds.) Respiratory Function of the Upper Airway Marcel Dekker, New York.*
- Bosma J. F., Doty R.W. (1956) An electromyographic analysis of reflex deglutition  
*Journal of Neurophysiology* 19 : 44-60.
- Bowen-Jones A., Thomson C., Drewett R. F. (1982) Milk flow and sucking rates during breast feeding  
*Developmental Medicine and Child Neurology* 24 : 626-633.
- Bradley R. M., Mistretta C. M. (1975) Fetal Sensory Receptors.  
*Physiological Review* 55 : 352.
- Brake S. C., Fifer W. P., Alfasi G., Fleischman A. (1988) The First Nutritive Sucking Responses of Premature Newborns  
*Infant Behavior and Development* 11 : 1-19.

- Braun M.P., Palmer M.A. (1986) A pilot study of oral motor dysfunction in "at risk" infants  
*Physical and Occupational Therapy in Pediatrics* 5(4) : 13-25.
- Brazelton T. B. (1973) Neonatal Behavioral Assessment Scale  
*Spastics International Medical Publications Clinics in Developmental Medicine*, J. B. Lippincott, Philadelphia.
- Brazelton T. B. (1994) Behavioral competence *In* G.B. Avery, M.A. Fletcher, M.G. Macdonald (Eds.) Neonatology: Pathophysiology and Management of the Newborn J.P. Lippincott, Philadelphia.
- Brazelton T. B., Nugent J. K (1995) Neonatal Behavioral Assessment Scale (3rd. Edition) *Mac Keith Press, London*.
- Brazy J. E. (1988) Effect of crying on cerebral volume and cytochrome aa3  
*Journal of Pediatrics* 112 :457-461.
- Brimblecombe F. S. W., Richards M. P. M., Robertson N. R. C. (1978) Separation and special care baby units *Clinics in Developmental Medicine* No 68, SIMP, London.
- Brooke O. G., Alvear J., Arnold M. (1979) Energy Retention, Energy Expenditure, and Growth in Healthy Immature Infants  
*Pediatric Research* 13 : 215-220.
- Bu'Lock F., Woolridge M., Baum J. D. (1990) Development of co-ordination of sucking, swallowing and breathing: Ultrasound study of term and preterm infants  
*Developmental Medicine and Child Neurology* 32 (8) : 669-678.
- Bull M., Lawrence D. (1985) Mother's use of knowledge during the first postpartum weeks  
*Journal of Obstetrics, Gynaecology and Neonatal Nursing* 14 (4) : 315-320.
- Butte N. F., Jenson C. L., Moon J. K., Glaze D. G., Frost J. D. (1992) Sleep Organization and Energy Expenditure of Breast-Fed and Formula-Fed Infants  
*Pediatric Research* 32 (5) : 514-519.
- Caesar P. H., Daniels H., Devlieger H., DeCock P., Eggermont E. (1982) Feeding behavior in preterm infants  
*Early Human Development* 7 : 331-346.
- Carter D. E. (1991) Qualitative Research  
*In* D.F.S. Cormack (Ed.) The Research Process in Nursing. (2nd Edition) Blackwell Scientific Publication, Oxford.

- Case-Smith J., Cooper P., Scala V. (1988) Feeding efficiency in the premature neonate  
*American Journal of Occupational Therapy* 43(4) : 245-250.
- Chessex P., Reichman B. L., Verellen G. J. E., Putet G., Smith J. M., Heim T., Swter P. R. (1981) Relation between Heart Rate and Energy Expenditure in the Newborn  
*Pediatric Research* 15 : 1077-1082.
- Cooper-Evans J. (1991) Incidence of hypoxaemia associated with caregiving in premature infants  
*Neonatal Network* 10(2) : 17-24.
- Cormack D. F. S. (1991) The Research Process in Nursing (2nd Edition)  
Blackwell Scientific Publication, Oxford.
- Cowan W. M., Fawcett J. W., O'Leary D. D. M., Stanfield B. B. (1984) Regressive events in neurogenesis  
*Science* 225 : 1258-1265.
- Cranston Anderson J., Behnk M., Gill N. E., Conlon M., Porter Measel C., McDonie T. E. (1990) Self-regulatory Gavage-to-Bottle Feeding for Preterm Infants: Effects on Behavioral State, Energy Expenditure, and Weight Gain In S. G. Funk, E. M. Tornquist, M. T. Champagne, L. A. Copp, R. A. Weise (Eds.) Key Aspects to Recovery-Improving Infant Nutrition, Rest, and Mobility , Springer Publishing Company, New York.
- Cunningham S., Deere S., Elton R. A., McIntosh N. (1992) Neonatal physiological trend monitoring by computer  
*International Journal of Clinical Monitoring and Computing* 9 : 221-227.
- D'Apolito K. (1991) What is an organised infant?  
*Neonatal Network* 10 (1) : 23-29.
- Daniels H., Devlieger H., Casaer P., Ramaeker V., Van den BraeckJ., Eggermont E. (1988) Feeding , behavioural state and cardiorespiratory control  
*Acta Paediat. Scand* 77 : 369-373.
- Davis M. K., Savitz D. A., Granbard B. I. (1988) Infant feeding and childhood cancer  
*Lancet* 2 (8607) : 365-368.

- DeHaan R., Patrick J., Chess G. F., Jaco N. T. (1977) Definition of sleep state in the newborn infant by heart rate analysis  
*American Journal of Obstetrics and Gynecology* 127 : 753-758.
- Dietch J. S. (1993) Periventricular-intraventricular haemorrhage in the very low birth weight infant  
*Neonatal Network* 12(1) : 7-16.
- DiPietro J. A., Porges S. W. (1990) Vagal Responsiveness to Gavage Feeding as an Index of Preterm Status  
*Pediatric Research* 29 (3) : 231-236.
- DiPietro J. A., Cusson R. M., O'Brien Caughy M., Fox N. A. (1994) Behavioral and Physiologic Effects of Nonnutritive sucking during Gavage Feeding in Preterm Infants  
*Pediatric Research* 36 (2) : 207-214.
- Downs J. A., Edwards A. D., McCormick D. C., Roth S. C., Stewart A. L. (1991) Effect of intervention on development of hip posture in very preterm babies  
*Archives of Diseases in Childhood* 66 : 797-801.
- Drewett R. F., Woolridge M. (1979) Sucking patterns of human babies on the breast  
*Early Human Development* 3 : 321-328.
- Dubignon J., Cooper D. (1980) Good and poor feeding behavior in the neonatal period  
*Infant Behavior and Development* 3 : 395-408.
- Field P. A., Morse J. M. (1985) Nursing Process: the application of qualitative approaches  
*Croom Helm, London*.
- Field T. M., Goldson E. (1984) Pacifying effects of non-nutritive sucking on term and preterm neonates during heelstick procedures  
*Pediatrics* 74 : 1012-1015.
- Field T. M., Schanberg S. M. (1987) Sensory deprivation stress and supplemental stimulation in the rat pup and preterm human neonate  
*Child Development* 58 : 1431-1447.
- Field T. (1990) Alleviating Stress in Newborn Infants in The Intensive Care Unit.  
*Clinics in Perinatology* 17 : 1-9.

- Garg M., Kurzner S. I., Bautista D. B., Keens T. G. (1988) Clinically unsuspected hypoxia during sleep and feeding in infants with bronchopulmonary dysplasia.  
*Pediatrics* 81 : 635-642.
- Gill N. E., Behnke M., Conlon M., McNeely J. B., Anderson G. C. (1988) Effect of Nonnutritive Sucking on Behavioural State In Preterm Infants Before Feeding  
*Nursing Research* 37 (6) : 347-350.
- Gilles F. H., Leviton A., Dooling E. C. (1983) The Developing Human Brain  
John Wright, Boston.
- Gorski P. A. (1982) Premature infant behavioral and physiological responses to caregiving interventions in an intensive care nursery  
In J.D. Call, E. Galenson, R.L. Tyson (Eds.) Frontiers in Infant Psychiatry Basic Books, New York.
- Gorski P. A., Hole W.T., Leonard C.H. (1983) Direct computer recording of premature infants and nursery care  
*Pediatrics* 72 (5) : 198-202
- Gorski P. A., Huntington L., Lewkowicz D. J. (1990) Handling preterm infants in hospitals. Stimulating controversy about timing of intervention.  
*Clinics in Perinatology* 17 (1) : 103-112.
- Gottfried A. W., Gaiter J. L. (1985) Infant Stress Under Intensive Care  
University Park Press, Baltimore.
- Grosvenor C. E., Picciano M. F., Baumrucker C. R. (1993) Hormone and growth factors in milk  
*Endocrine Review* 14 (6) : 710-728.
- Gryboski J. D. (1969) Suck and Swallow in the Premature Infant  
*Pediatrics* 43 : 96-102
- Guilleminault C., Coons S. (1984) Apnea and bradycardia during feeding in infants weighing > 2000 gms  
*Journal of Pediatrics* 104 : 932-935.
- Gunther M. (1945) Sore nipples; causes and prevention  
*Lancet* 2 : 590-593.
- Hack M., Estabrook M. M., Robertson S. S. (1985) Development of sucking rhythms in preterm infants  
*Early Human Development* 11 : 133-140.



- Hallet C. (1995) Understanding the phenomenological approach to research  
*Nurse Research* 3 (2) : 55-65.
- Harris, M. B. (1986) Oral motor management of the high-risk neonate.  
*Physical and Occupational Therapy in Pediatrics* 6 : 231-253.
- High P. C., Gorski P. A. (1985) Womb for Improvement: A study of preterm development in an intensive care nursery *In* A. W. Gottfried, J. L. Gaiter (Eds.) *Infant Stress Under Intensive Care*. University Park Press, Baltimore.
- Holditch-Davis D. (1990) The Development of Sleeping and Waking States in High Risk Preterm Infants  
*Infant Behaviour and Development* 13 : 513-531.
- Huch R., Huch A. (1981) Continuous PO<sub>2</sub> and PCO<sub>2</sub> monitoring in the neonate  
*Journal of Perinatal Medicine* 9 : 200-203.
- Humphrey T. (1965) Function of the nervous system during prenatal life  
*In* U. Stave (Ed.) *Prenatal Physiology* Plenum Press, New York.
- Ianniruberto A., Tajani E. (1981) Ultrasonographic study of fetal movements  
*Seminars in Perinatology* 5 : 175-181.
- Illingworth R. S., Lister J. (1964) The critical or sensitive period, with special reference to certain feeding problems in infants and children  
*Journal of Pediatrics* 65 : 839.
- Inoue N., Sakashita R., Kamegai T. (1995) Reduction of masseter muscle activity in bottle-fed babies  
*Early Human Development* 42 : 185-193.
- Jones E. (1994) Breast feeding in the preterm infant  
*Midwife* 4, pp. 22-26.
- Koenig J. S., Davies A. M., Thach B. T. (1990) Coordination of breathing, sucking and swallowing during bottle feeding  
*Journal of Applied Physiology* 69 (5) : 1623-1629.
- Koletzko S., Sherman P., Carey M. (1989) Role of infant feeding practices in development of Crohn's disease in childhood  
*British Medical Journal* 298 (6688) : 1617-1618.



- Kuhn T. S. (1970) International Encyclopedia of Unified Science. The Structure of Scientific Revolution. (2nd Edition) *University of Chicago Press, Chicago.*
- Lang S., Lawrence C. J., L' E Orme R. (1993) Cup feeding: an alternative method of infant feeding  
*Archives of Disease in Childhood* 71 : 365-369.
- Lawrence R. A. (1989) Breast feeding : A guide for the medical profession C. V. Mosby, St. Louis.
- Lau C., Henning S. J. (1989) A Noninvasive Method for Determining Patterns of Milk Intake in the Breast-Fed Infant  
*Journal of Pediatric Gastroenterology and Nutrition* (4) : 481-487.
- Leaf A. (1996) Essential fatty acids in neonatal nutrition  
*Seminars in Neonatology* 1 :1 pp. 43-50
- Lees M. H., Bristow J. D., Way C., Brown M. (1967) Cardiac output by Fick principle in infants and young children  
*American Journal of Diseases in Children* 114 : 144.
- Leininger M. M. (1985) Qualitative Research Methods in Nursing Grunne & Stratton, Orlando.
- LoBiondo-Wood G., Haber J. (1994) Nursing Research. Methods, Critical Appraisal and Utilisation (3rd. Edition) C.V. Mosby, St. Louis.
- Logeman J. A. (1983) Diagnosis and treatment of swallowing disorders College-Hill Press, San Diego.
- Long J. C., Alistair G. S., Philip M. B., Lucey J. F. (1980a) Excessive handling as a cause of hypoxemia  
*Pediatrics* 65 : 203-207.
- Long J. C., Lucey J. F., Philip M. B. (1980b) Noise and hypoxemia in the intensive care nursery.  
*Pediatrics* 65 : 143-145.
- Lott J. W. (1989) Developmental care of the preterm infant  
*Neonatal Network* 7 : 21-28.
- Lucas A., Lucas P. J., Baum J. D. (1979) Pattern of milk flow in breast fed infants  
*Lancet* 2 : 57-58.
- Lucas A., Bloom S. R., Aynsley-Green A. (1980) Development of gut hormone responses to feeding neonates  
*Archives of Disease in Childhood* 55 : 678-682.

- Lucas A., Lucas P. J., Baum J. D. (1981) Differences in the pattern of milk intake between breast and bottle-fed infants  
*Early Human Development* 5 : 195-199.
- Lucas A., Cole T. J. (1990) Breast milk and neonatal necrotising enterocolitis  
*Lancet* 335 : 1519-1523.
- Lucas A., Morley R., Cole T. J., Gore S. M. (1994) A randomised multi-centre study of human milk versus formula and later development in preterm infants  
*Archives of Disease in Childhood* 70 :2) : F141-146.
- Ludington S. M. (1990) Energy conservation during skin-to-skin contact between premature infants and their mothers  
*Heart and Lung* 19 (5) :445-451
- Masterson J., Zucker C., Schultz K., (1987) Prone and supine positioning effects on energy expenditure and behavior in low birth weight neonates  
*Pediatrics* 80 : 689-692.
- Mathew O. P., Clark M. L., Pronske M. H., Luna-Solarzano H. G., Peterson M. D. (1985) Breathing pattern and ventilation during oral feeding in term newborn infants  
*Journal of Pediatrics* 106 : 810-813.
- Mathew O. P. (1988) Respiratory control during nipple feeding in preterm infants  
*Pediatric Pulmonology* 5 : 220-224.
- Mathew O. P., Bhatia J. (1989) Sucking and breathing patterns during breast- and bottle -feeding in term neonates. Effects of nutrient delivery and composition  
*American Journal of Diseases in Children* 143 : 588- 592.
- Mathew O. P. (1991) Medical Progress: Science of bottle feeding  
*Journal of Pediatrics* 119 : 511-519.
- Matthew M. K. (1988) Developing an instrument to assess infant breast feeding behaviour in the early neonatal period  
*Midwifery* 4 : 154-165.
- McCain G. C. (1992) Facilitating Inactive Awake States In Preterm Infants: A Study Of Three Interventions  
*Nursing Research* 41 : 3 : 157-160.

- McCormick M. C., Gortmaker S. L., Sobol A. M. ( 1990) Very Low Birthweight Children: behavior problems and school difficulty in a national sample  
*Journal of Pediatrics* 117 : 687.
- McCalla S., Minkoff H. L., Fieldman J. G. (1991) The biological and social consequences of perinatal cocaine use in inner-city populations: results on an anonymous cross-sectional study  
*American Journal of Obstetrics and Gynaecology* 164 : 625-630.
- McFarland D. H., Lund J. P., Gagner M. (1994) Effects of posture on the coordination of respiration and swallowing  
*Journal of Neurophysiology* (5) : 2431-2437.
- McFarlane of Llandaff (1991) Forward  
*In D. F. S. Cormack (Ed) The Research Process in Nursing (2nd Edition) Blackwell Scientific Publication, Oxford.*
- Medoff-Cooper B., Weininger S., Zukowsky (1989) Neonatal Sucking as a Clinical Assessment Tool: Preliminary Findings  
*Nursing Research* 38 (3) : 162-165.
- Medoff-Cooper B. (1991) Changes in Nutritive Sucking Patterns with Increasing Gestational Age  
*Nursing Research* 40 (4) : 245-247.
- Medoff-Cooper B., Verklan T., Carlson S. (1993) The Development of Sucking Patterns and Physiological Correlates In Very-Low-Birth-Weight Infants  
*Nursing Research* 42 (2) : 100-105.
- Meier P., Pugh E. J. (1985) Breast feeding behavior of small preterm infants  
*American Journal of Maternal and Child Nursing* 10 : 396-401.
- Meier P., Anderson G. C. (1987) Responses of small preterm infants to bottle and breast feeding  
*American Journal of Maternal and Child Nursing* 12 : 97-105.
- Meier P. (1988) Bottle and Breast Feeding : Effects on Transcutaneous Oxygen Pressure and Temperature in Preterm Infants  
*Nursing Research* 37 : 36-41.
- Meier P. (1990) Nursing Management of Breast Feeding for Preterm Infants *In S. G. Funk, E. M. Tornquist, M. T. Champagne, L.A. Copp, R. A. Wiese (Eds.) Key Aspects of Recovery- Improving Nutrition, Rest and Mobility Springer Publishing, New York.*

- Merenstein G. B., Gardener L. S. (1993) Handbook of Neonatal Intensive Care, (3rd. Edition) *Moseby, St. Louis*.
- Miller B., Sollie D. (1980) Normal stresses during the transition to parenthood  
*Family Relations* 29 : 459-465.
- Moore K. E. (1988) The developing human: clinically orientated embryology (4th Edition) *W. B. Saunders, Philadelphia*.
- Morris S. (1982) The normal acquisition of oral feeding skills: Implications for assessment and treatment *Therapeutic Media, New York*.
- Morris S. E., Klein M. D. (1987) Pre-feeding skills: A comprehensive Resource for Feeding Development Therapy Skill Builders, *Tucson*.
- Naeya R. L. (1992) Disorders of the placenta, fetus and neonate, their diagnosis and clinical significance *C.V. Mosby, St. Louis*.
- Neifert M., Lawrence R., Seacot J. (1996) Nipple Confusion: Toward a formal definition  
*Journal of Pediatrics* 126 (6) : S125-S129.
- Norris S., Campbell L., Brenkert S. (1982) Nursing procedures and alterations in transcutaneous oxygen tension in premature infants  
*Nursing Research* 31 : 330-336.
- Oehler J. M., Eckerman C. O., Wilson W. H. (1988) Social stimulation and the regulation of premature infants state prior to term age  
*Infant Behaviour and Development* 11 : 333-351.
- Orem J. Barnes C.D. (1980) Physiology in Sleep *Academic Press, New York*.
- Parmelee A. H., Stern E. (1972) Development of states in infants  
*In Clemente C., Purpura O., Mayer F. (Eds.) Sleep and the maturing nervous system. Academic Press, New York*.
- Piontelli A. (1992) From Fetus to child. Observation and Psychoanalytical Study *Tavistock Routledge, London*.
- Polit D. F., Hungler B. P (1991) Nursing Research. Principles and Methods (4th Edition) *J.P. Lippincott Comp., Philadelphia*.
- Presly A. S. (1991) Experimental Research *In D.F.S. Cormack (Ed.) The Research Process in Nursing. (2nd Edition) Blackwell Scientific Publication, Oxford*.

- Rosen C. L., Glaze D. G., Frost J. D. (1984) Hypoxemia associated with feeding preterm infants and full term neonates  
American Journal Diseases in Children 138 : 623-628.
- Ross Russel R.I., Helms P.J. (1994) Evaluation of three different techniques used to measure chest wall movements in children  
European Respiratory Journal 7 : 2073-2076.
- Rubin R. (1984) Maternal tasks in pregnancy  
American Journal of Maternal and Child Nursing 19 (2) : 143-151.
- Rush D. (1993) Maternal Nutritional Deficiencies in Industrialised Countries In J.D. Baum (Ed.) Birth Risks Nestle Nutrition Workshop Vol 31, Nestle Ltd., Switzerland.
- Saigal S., Lunyk O., Bryce-Larke R. P., Chernesksy M. A. (1982) The outcome in children with congenital CMV infection: a longitudinal follow-up study  
American Journal of Diseases in Children 136 : 896-901.
- Sarnat H. B. (1984) Anatomic and physiologic correlates of neurologic development in prematurity In H.B. Sarnat (Ed.) Topics in Neonatal Neurology Grune & Stratton, New York.
- Scottish Health Service Common Services Agency (1981) Scottish Health Statistics CSA, Edinburgh.
- Scottish Health Service Common Services Agency (1992) Scottish Health Statistics CSA, Edinburgh.
- Selley W. G., Ellis R. E., Flack F. C., Brooks W. A. (1990) Co-ordination of Sucking, Swallowing and Breathing in the Newborn: Its relationship to infant feeding and normal development  
British Journal of Disorders of Communication 25 : 311-327.
- Shaker C. S. (1990) Nipple feeding premature infants: A different perspective  
Neonatal Network 8 : 9-17.
- Shivpuri C. R., Martin R. J., Carlo W. A., Fanarof A. A. (1983) Decreased ventilation in preterm infants during oral feeding  
Journal of Pediatrics 103 : 285-289.
- Smith W. L., Erenberg A., Nowak A. (1985) Physiology of sucking in the normal term infant using real-time ultrasound  
Radiology 156 : 379-381.

- Smith W. L., Erenberg A., Nowak A. (1988) Imaging evaluation of the human nipple during breast feeding  
*American Journal of Diseases in Children* 142 : 76-78.
- Spinelli D. N. (1990) Plasticity Triggering Experiences, Nature and the Dual Genesis of Brain Structure and Function  
*Clinics in Perinatology* 17 (1) : 77-82.
- Steel M. (1987) Caring for parents of critically ill neonates during hospitalisation: Strategies for health care professionals  
*American Journal of Maternal and Child Nursing* 16 (1) : 13-27.
- Stefanski M., Schulze K., Bateman D., Kairam R., Pedley T.A., Masterson J., James L.S. (1984) A scoring system for states of sleep and wakefulness in the term and preterm infant  
*Pediatric Research* 18 : 58-62.
- Stevenson R. D., Allaire J. A. (1991) The development of normal feeding and swallowing  
*Pediatric Clinics of North America* 38 (6) : 1439-1453.
- Stjernquist K. (1992) Extremely low birth weight infants <901 g. Impact on the family during the first year  
*Scand. J. Soc. Med.* 20 : 123-156.
- Symon A., Cunningham S. (1994) Nasogastric feeding methods in neonates  
*Nursing Times* 90 (35) : 56-59.
- Taylor P. M., Taylor F. H., Maloni J. A., Campbell S. B., Cannon M. (1985) Effects of Extra Early Mother-Infant Contact  
*Acta Paediat. Scand.* 316 : S15-22
- Thoman E. B. (1990) Sleeping and waking states in preterm infants: A functional Perspective  
*Neuroscience and Behavioral Reviews* 14 : 93-107.
- Timms B. J. M., DiFiore J. M., Martin R. T., Miller M. J. (1993) Increasing respiratory drive as an inhibitor of oral feeding in preterm infants  
*Journal of Pediatrics* 123 ( 1) : 127-131.
- Tuchmann D. D. (1988) Dysfunctional Swallowing in the Pediatric Patient: Clinical Considerations  
*Dysphagia* 2 : 203.



- Tucker J. (1985) Perspective of the development of the air and food passages  
*American Review of Respiratory Disease* 131 : S7-S9.
- United Kingdom Central Council for Nursing, Midwifery and Health Visiting (1992)  
*The Scope of Professional Practice* London.
- Urdike C., Schludt R. E., Macke C., Cahoon J., Miller M. (1986)  
Positional support for premature infants  
*American Journal of Occupational Therapy* 40 : 712-715.
- VandenBerg K. A. (1990) Nippling management of the sick neonate in the NICU : The disorganised feeder  
*Neonatal Network* 9 : 9-16.
- Vice F. L., Heinze J. M., Guirati G., Hood M., Bosma J. F. (1990) Cervical Auscultation of suckle feeding in newborn infants  
*Developmental Medicine and Child Neurology* 32 : 760-768.
- Virtanen S. M., Aro A. (1994) Dietary factors in the aetiology of diabetes  
*(Review) Ann. Med.* 26 (6) :469-478.
- Volpe J. J. (1987) *Neurology of the Newborn* W. B. Saunders, Philadelphia.
- Weaver L. T. (1996) The infant and enteromammary axis  
*Presentation, XVth European Congress of Perinatal Medicine.*
- Webb W. B. (1983) Theories in modern sleep research *In* A. Mayes (Ed.)  
*Sleep mechanisms and functions in humans and animals- an evolutionary perspective* Van Nostrand Reinhold, London.
- Weber F., Woolridge M. W., Baum J. D. (1986) An ultrasonographic study of the organisation of sucking and swallowing by newborn infants  
*Developmental Medicine and Child Neurology* 28 : 19-24.
- White-Traut R. C., Nelson M. N. (1988) Maternally administered tactile, auditory, visual and vestibular stimulation: Relationship to later interactions between mothers and premature infants  
*Research in Nursing and Health* 11 : 31-39.
- White-Traut R. C., Silvestin J. M., Nelson M. N., Patel M. K., Kilgallon D. (1993) Patterns of physiologic and behavioral response of intermediate care preterm infants to intervention  
*Pediatric Nursing* 19(6) : 625-629.
- Williams A. T. (1994) Is breast feeding beneficial in the U.K?  
*Archives of Disease in Childhood* 71 (4) : 376-380.



- Wolf L. S., Glass R. P. (1992) Feeding and Swallowing Disorders in Infancy  
*Therapy Skill Builders, Tuscon.*
- Wolff P. H. (1968) The serial organisation of sucking in the young infant  
*Pediatrics* 42 : 943-956.
- Wong W.W. (1995) Early feeding and regulation of cholesterol metabolism  
*36th Nestle Nutrition Workshop. Nestle Ltd., Switzerland.*
- Woodson R. H., Field T., Greenberg R. (1983) Estimating Neonatal Oxygen Consumption from Heart Rate  
*Psychophysiology* 20 (5) : 558-561.
- Woodson R., Drinkwin J., Hamilton C. (1985) Effects of Nonnutritive Sucking on State and Activity: Term -Preterm Comparisons  
*Infant Behaviour and Development* 8 : 435-441.
- Woodson R., Hamilton C. (1988) The effect of non-nutritive sucking on heart rate in preterm infants  
*Developmental Psychobiology* 21 : 207-213.
- Woolridge M.W., How T.V., Drewett R.F., Rolfe P., Baum J.D. (1982) The continuous measurement of milk intake at a feed in breast-fed babies  
*Early Human Development* 6 : 365-373.
- Woolridge M. W. (1986) "The 'anatomy' of infant sucking".  
*Midwifery* 2 : 164-171.
- Yakovlev P. L., Lecours A. R. (1967) The myelogenetic cycles of regional maturation of the brain *In A.Minkowski (Ed.) Regional development of the brain in early life F.A. Davis, Philadelphia.*
- Young B., Drewett R., Chetwynd A., Diggie P. (1996) Sucking patterns in breast fed babies  
*Paper presented at the Society for Reproductive and Infant Psychology Conference, Leicester.*

# **APPENDIX**

	Total feeding time (seconds)	Continuous sucking time (seconds)	Mean burst time (seconds)	Mean pause time (seconds)
Mean	1063.67	41.67	11.55	16.41
s.e.	138.45	16.11	1.55	2.34

Overall time	Sucks/ (seconds)	Swallows/ (seconds)	Breaths/sec. (sucking)	Breaths/sec. (pause)	Breaths/ (seconds)
Mean	1.13	.73	.91	.96	.94
s.e.	.04	.09	.05	.06	.05

Continuous sucking	Sucks/second	Swallows/ second	Breaths/ second	Sucks/ swallow	Breaths/ swallow	Sucks/ breath
Mean	1.14	.57	.92	2.35	1.89	1.27
s.e.	.06	.13	.07	.59	.53	.08

Intermittent sucking	Sucks/second	Swallows/ second	Breaths/ second	Sucks/ swallow	Breaths/ swallow	Sucks/ breath
Mean	1.14	.75	.91	1.78	1.45	1.28
s.e.	.04	.09	.05	.28	.25	.08

Appendix Table 1. Time (seconds) of the various components of feeding. The mother-infant dyads monitored to gather information on the reliability and usefulness of the equipment were multiparous women who had previously breast fed and were currently successfully breast feeding their new term infant.

### **Eyes Open or Closed**

- 12 Hard crying: very red face; clenched fists; very prolonged exhalation; audible or silent cry; entire body very tense
- 11 Crying: prolonged exhalation; audible or silent cry; general body tension; (red face)
- 10 Fussing: normal colour; single or frequent slightly prolonged exhalation; whimper; (precry grimace; snorts)

### **Eyes Open**

- 9 Very active awake: total body movement; (twisting or lifting head or trunk; turning head side to side)
- 8 Active awake: whole limb movement: (twisting or lifting trunk or head slowly or slightly)
- 7 Quiet awake: eyes don't fix and follow; no movement or slight slow movement of head, face, hand, forearm, foot or lower leg
- 6 Alert inactivity: eyes are wide open, quiet, luminous, fixated; no or slight movement of head, face, hand, forearm, foot or lower leg; (eye contact; eyes follow)

### **Eyes Opening and Closing Slowly**

- 5 Drowsy: quiet or some movement; eyes dull or glazed; heavy lidded; (drowsy waking up tends to be more active)

### **Eyes Closed**

- 4 Very active sleep: total body movement; (twisting or lifting head or trunk; turning head side to side)
- 3 Active sleep: irregular respirations; whole limb movement; (twisting or lifting trunk or head slowly or slightly: facial grimaces)
- 2 Irregular quiet sleep: irregular respirations; no movement or slight, slow movement of face, head, hand, forearm, foot or lower leg; (brief apnoea)
- 1 Regular quiet sleep: regular respirations; faint or no movement; (slight mouthing or movement of fingers and toes)

Items in parentheses need not be present.

Appendix Table 2 Anderson Behavioural State Scale (ABSS)

POST MENSTRUAL AGE AT TIME OF FEED (weeks)

31	32	33	34	35	36	37
n=3	n=3	n=10	n=6	n=6	n=2	n=2

FEED PARAMETER

sucks/burst (no.)

(mean)	7.09	7.73	9.53	10.32	9.16	8.58	9.34 *
(s.e.)	.7	1.69	1.91	1.87	1.49	1.55	2.25

swallows/burst (no.)

(mean)	3.24	1.94	3.46	5.37	4.74	2.44	5.64 **
(s.e.)	.24	.13	.69	1.38	1.39	.52	2.31

breaths/burst (no.)

(mean)	6.29	7.47	8.47	8.82	8.95	6.89	7.86
(s.e.)	1.14	1.07	1.85	2.31	1.65	1.16	2.51

breaths/pause (no.)

(mean)	11.43	60.26	19.97	16.89	13.52	16.08	11.43
(s.e.)	1.11	34.53	3.77	2.63	2.29	2.69	2.54

Appendix Table 3 Frequency of sucking, swallowing and breathing per  
burst/pause of the intermittent sucking phase

# POST MENSTRUAL AGE AT TIME OF FEED (weeks)

	31	32	33	34	35	36	37
	n=3	n=3	n=10	n=6	n=6	n=2	n=2
FEED PARAMETER							
sucking: swallowing							
(mean)	2.72	8.5	3.05	3.36	5.14	4.5	2.04
(s.e.)	1.05	1.5	.51	.56	1.46	.5	.47
breathing: swallowing							
(mean)	1.61	10.33	2.59	3.43	5.49	5.13	1.39
(s.e.)	.32	2.6	.44	.9	1.78	2.13	.11
sucking: breathing							
(mean)	1.39	.89	1.18	1.13	.98	1.23	1.4
(s.e.)	.31	.1	.13	.1	.05	.35	.22

Appendix Table 4 Ratio of sucking:swallowing:breathing during continuous sucking

## POST MENSTRUAL AGE AT TIME OF FEED (weeks)

	31	32	33	34	35	36	37
	n=3	n=3	n=10	n=6	n=6	n=2	n=2
<b>FEED ELEMENT</b>							
sucking: swallowing							
(mean)	2.21	4.11	2.95	2.13	2.72	3.58	1.79
(s.e.)	.27	1.11	.032	.27	.61	.43	.33
breathing: swallowing							
(mean)	1.99	3.91	2.7	1.74	2.56	2.87	1.46 *
(s.e.)	.46	.71	.05	.27	.58	.18	.15
sucking: breathing							
(mean)	1.17	1.03	1.23	1.27	1.06	1.25	1.22
(s.e.)	.13	.13	.15	.12	.06	.16	.11

Appendix Table 5 Ratio of sucking:swallowing:breathing during intermittent sucking



PMA. code	burst/ pause no.	no. of suck	nutritive suck/sec. mean (s.d.)	no. of breath	nutritive breaths/sec. mean (s.d.)	nutritive swall./sec. mean (s.d.)	no. of non- nutr. suck	non-nutritive suck/sec. mean (s.d.)	no. of non- nutr. breath	non-nutritive breaths/sec. mean (s.d.)	time to 2:1 sucks: swallow	no. of breath	pause breaths/sec. mean (s.d.)	feed score
31.1	39	219	.89 (.27)	158	.48 (.39)	.32 (.3)	52	.98 (.33)	38	.47 (.46)	180	457	1.12 (.39)	13
31.2	34	299	1.00 (.31)	254	.76 (.38)	.44 (.38)	23	1.03 (.50)	21	.68 (.41)	0	306	1.19 (.27)	15
31.3	55	423	.85 (.23)	446	.75 (.3)	.31 (.28)	67	.86 (.25)	82	.8 (.38)	40	728	1.03 (.23)	12
32.4	13	81	.77 (.24)	100	.95 (.26)	.21 (.21)	17	.82 (.32)	20	1.09 (.30)	899	1422	1.01 (.14)	8
32.5	49	541	1.17 (.20)	467	1.18 (.2)	.13 (.04)	98	1.21 (.27)	88	1.0 (.17)	33	1142	1.41 (.31)	9
32.6	22	149	1.3 (.46)	132	1.02 (.43)	.42 (.43)	51	1.55 (.75)	38	.97 (.59)	80	590	1.08 (.31)	11
33.7	61	370	1.37 (.39)	248	.82 (.32)	.33 (.32)	57	1.56 (.52)	35	.93 (.38)	47	551	.93 (.20)	12
33.8	18	622	1.25 (.35)	649	1.08 (.35)	.47 (.44)	63	1.48 (.35)	52	1.23 (.39)	21	707	1.13 (.21)	12
33.9	94	512	1.16 (.20)	475	1.04 (.19)	.39 (.19)	28	1.42 (.12)	21	.93 (.37)	57	848	1.28 (.21)	15
33.10	21	312	1.49 (.26)	226	.98 (.20)	.4 (.26)	49	1.65 (.24)	27	.91 (.3)	130	749	1.1 (.22)	13
33.11	20	87	.47 (.09)	131	.62 (.26)	.35 (.27)	9	.45 (.11)	16	.78 (.22)	0	328	.98 (.32)	12
33.12	41	781	1.49 (.33)	404	.70 (.31)	.44 (.27)	72	1.66 (.50)	38	.89 (.31)	19	777	.98 (.29)	15
33.13	83	422	1.53 (.27)	222	.8 (.29)	.54 (.27)	10	1.67	6	1.0	0	466	1.13 (.28)	12
33.14	21	140	1.11 (.31)	134	1.0 (.20)	.53 (.32)	2	2.0	2	1.0	0	449	.94 (.23)	13
33.15	26	166	.8 (.22)	230	1.0 (.27)	.21 (.24)	24	.92 (.24)	22	1.03 (.40)	0	313	.94 (.22)	7
33.16	14	87	.86 (.36)	81	.80 (.45)	.23 (.11)	2	2.0	2	2.0	73	354	1.19 (.25)	8

Table 6 Differences in feeding elements and scores both within and between feeds (PMA31-33 weeks; continued)

Abbreviations: swallow. = swallows, sec. = seconds, nutr. = nutritive, feed score = feeding assessment tool (page 76)

PMA. code	burst/ pause no	no. of suck	nutrative suck / sec. mean (s.d.)	no. of breath	nutrative breaths/sec. mean (s.d.)	snutrative wall./sec. mean (s.d.)	no. of non- nutr. sucks	non nutrative sucks/sec. mean (s.d.)	no. of non- nutr. breath	non nutrative breath/sec. mean (s.d.)	Time to 2:1 sucks: swallow	no. of breath	pause breaths/sec mean (s.d.)	pre feed score
34.17	87	1318	1.04 (.16)	1128	.91 (.22)	.33 (.14)	24	1.17 (.41)	22	1.12 (.34)	98	852	1.05 (.22)	15
34.18	24	386	.77 (.23)	439	.91 (.23)	.54 (.22)	0	0	0	0	18	382	1.04 (.26)	11
34.19	80	804	1.28 (.27)	511	.74 (.28)	.65 (.28)	4	1.33	4	1.33	38	798	.94 (.30)	17
34.20	31	282	1.35 (.34)	177	.75 (.43)	.61 (.44)	18	1.79 (.25)	12	1.12 (.63)	12	481	.92 (.32)	17
34.21	25	133	1.16 (.33)	122	1.05 (.60)	.47 (.35)	25	1.17 (.49)	35	1.7 (.80)	97	588	1.24 (.33)	11
34.22	18	144	1.09 (.24)	120	.73 (.42)	.65 (.27)	0	0	0	0	40	411	1.32 (.25)	14
35.23	25	211	1.04 (.27)	213	1.09 (.35)	.54 (.51)	18	1.23 (.37)	21	1.39 (.45)	0	387	1.2 (.24)	14
35.24	20	229	.94 (.12)	229	.93 (.24)	.78 (.31)	0	0	0	0	34	422	1.5 (.29)	17
35.25	31	495	.91 (.32)	507	1.03 (.35)	.28 (.2)	39	1.01 (.51)	46	1.37 (.59)	0	380	1.09 (.34)	8
35.26	44	436	1.08 (.27)	476	.97 (.35)	.24 (.21)	39	1.19 (.34)	31	.87 (.41)	58	472	1.18 (.35)	9
35.27	26	113	.91 (.18)	93	.71 (.25)	.23 (.26)	30	.89 (.15)	24	.62 (.26)	50	132	.94 (.26)	8
35.28	43	388	1.24 (.23)	325	1.05 (.40)	.53 (.22)	3	2.0	2	3.0	51	583	1.18 (.16)	18
36.29	76	696	1.12 (.38)	665	1.02 (.39)	.27 (.25)	67	1.23 (.57)	66	1.07 (.61)	57	1429	1.16 (.29)	8
36.30	44	272	1.29 (.50)	227	.86 (.33)	.37 (.34)	90	1.18 (.55)	77	.90 (.34)	34	747	1.13 (.17)	9
37.31	89	1122	1.18 (.17)	996	1.0 (.19)	.75 (.37)	25	1.43 (.34)	17	.94 (.34)	0	782	.81 (.19)	18
37.32	67	473	1.13 (.19)	356	.86 (.29)	.47 (.6)	22	1.13 (.20)	11	.61 (.45)	0	922	1.03 (.18)	15

Table 6 Differences in feeding elements and scores both within and between feeds (PMA 34-37 weeks)

PMA. code	mean sucks/sec.	Pearson correlation coefficient		sucking breath/sec. mean & s.d	Pearson correlation coefficient		pause breath/sec. mean & s.d	Pearson correlation coefficient	
		r <sup>2</sup>	df	p		r <sup>2</sup>	df	p	
31.1	.91 (.28)	.141	269	0.01pos	.56 (.41)	.01	194	NS	.028 455 NS
31.2	1.00 (.31)	.021	320	NS	.82 (.39)	.001	173	NS	.414 304 0.001pos
31.3	.85 (.23)	.05	188	NS	.78 (.3)	.002	526	NS	.086 726 0.05 pos
32.4	.78 (.25)	.331	96	0.05pos	.91 (.28)	.218	118	NS	.166 1420 NS
32.5	1.19 (.21)	.121	637	0.01pos	.95 (.2)	.003	553	NS	.061 1140 NS
32.6	1.4 (.41)	.02	198	NS	1.01 (.45)	3.274E-4	168	NS	.254 588 0.05 neg
33.7	1.39 (.42)	.002	425	NS	.81 (.33)	.007	281	NS	.027 549 NS
33.8	1.3 (.34)	.028	683	NS	1.05 (.35)	.002	699	NS	.019 705 NS
33.9	1.18 (.2)	.007	538	NS	1.09 (.17)	.013	494	NS	.037 846 NS
33.10	1.5 (.26)	.07	359	NS	1.01 (.21)	.001	451	NS	.005 747 NS
33.11	.46 (.1)	.007	94	NS	.69 (.25)	.163	145	NS	.231 326 0.05 neg
33.12	1.51 (.34)	.012	851	NS	.75 (.31)	.136	440	0.05neg	.379 775 0.001 neg
33.13	1.54 (.27)	.008	430	NS	.8 (.29)	.003	226	NS	.008 464 NS
33.14	1.11 (.31)	.01	140	NS	1.0 (.2)	.022	134	NS	.047 447 NS
33.15	.84 (.22)	.248	188	0.05neg	.94 (.3)	0.007	250	NS	1.563E-6 311 NS
33.16	.87 (.36)	.135	87	NS	.7 (.4)	.152	81	NS	.006 352 NS

Table 7 Mean and s.d. measurements of sucks and breaths/second during sucking and breaths/second during pause for within individual feeds (PMA 31-33 weeks). Pearson's correlation coefficient given; neg = negative correlation, pos = positive correlation

PMA. code	sucks/sec. mean & s.d	Pearson correlation coefficient r <sup>2</sup> df p	sucking breath/sec. mean & s.d	Pearson correlation coefficient r <sup>2</sup> df p	pause breath/sec. mean & s.d	Pearson correlation coefficient r <sup>2</sup> df p
34.17	1.03 (.17)	.025 1340 NS	.84 (.23)	.393 1148 0.001pos	1.05 (.22)	.132 850 0.001pos
34.18	.77 (.23)	.038 386 NS	.91 (.23)	.176 439 0.05 neg	1.04 (.26)	2.182E-5 380 NS
34.19	1.28 (.27)	.035 806 NS	.78 (.28)	.181 513 0.001neg	.94 (.30)	.189 797 0.001neg
34.20	1.36 (.33)	.002 298 NS	.82 (.44)	.05 187 NS	.92 (.32)	.016 479 NS
34.21	1.16 (.35)	.127 156 NS	1.0 (.61)	.001 155 NS	1.24 (.33)	.005 586 NS
34.22	1.09 (.24)	.071 144 NS	.73 (.42)	.253 120 0.05 neg	1.32 (.25)	.313 409 0.01 pos
35.23	1.05 (.27)	.041 227 NS	.97 (.37)	.003 232 NS	1.2 (.24)	.032 385 NS
35.24	.94 (.12)	.008 229 NS	.93 (.24)	.046 229 NS	1.5 (.29)	.269 420 0.05 pos
35.25	.92 (.33)	.014 532 NS	1.03 (.36)	.072 551 NS	1.09 (.34)	.015 378 NS
35.26	1.10 (.28)	.007 473 NS	1.11 (.35)	.091 505 0.05 neg	1.18 (.35)	.077 470 NS
35.27	.91 (.18)	.046 141 NS	.70 (.25)	.171 115 0.05 neg	.94 (.26)	.001 130 NS
35.28	1.24 (.23)	.174 389 NS	1.03 (.4)	.009 325 NS	1.18 (.16)	.023 581 NS
36.29	1.14 (.39)	.023 761 NS	1.03 (.4)	.009 729 NS	1.16 (.29)	.087 1427 0.01 neg
36.30	1.27 (.50)	.093 360 0.05 pos	.90 (.34)	.027 302 NS	1.13 (.17)	.049 745 NS
37.31	1.18 (.2)	.003 1145 NS	1.0 (.18)	.005 1011 NS	.81 (.19)	.058 780 0.05 neg
37.32	1.13 (.19)	.033 493 NS	.86 (.31)	4.625E-4 165 NS	1.03 (.18)	.024 920 NS

Table 7 Mean and s.d. measurements of sucks and breaths/second during sucking and breaths/second during pause for with individual feeds (PMA 33- 37 weeks). Pearson's correlation coefficient given; neg = negative correlation, pos = positive correlation

## ETHICAL CONSENT FORM

I, \_\_\_\_\_, agree to allow my baby, \_\_\_\_\_, to take part in the feeding study conducted by Sister Yvonne Freer. I have read the information sheet and have had opportunity to ask questions. I understand that my baby is under no obligation to take part and that I may withdraw from the study at any time without altering the care or treatment my baby may need or would normally receive. I also understand that my baby will not receive any benefit from the findings of the study.

Signature of Parent/Guardian

### INVESTIGATOR:

Sister Yvonne Freer,  
Neonatal Unit,  
Simpson Memorial Maternity Pavilion,  
Lauriston Place,  
Edinburgh.

Tel. 536 4296

Further information is available from Mrs. M. Howat, Clinical Nurse Specialist, Neonatal Unit,  
Simpson Memorial Maternity Pavilion, Lauriston Place, Edinburgh.

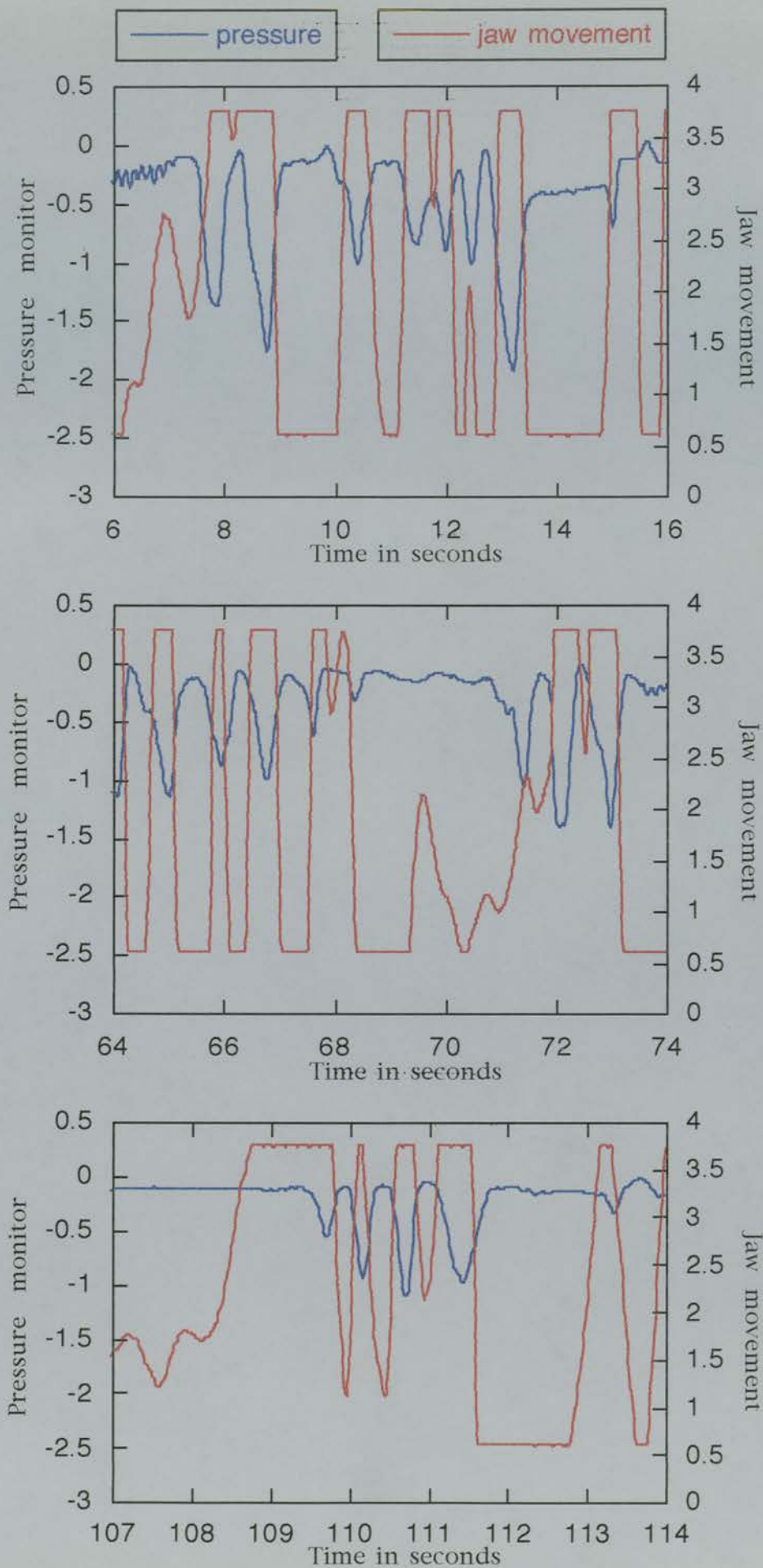
### Feeding study

As your baby has been born early, she may be too immature or weak to feed directly from you. Breast feeding like bottle feeding requires a lot of co-ordination of sucking, swallowing and breathing and often a baby who is born prematurely is unable to co-ordinate all these actions. Even when she can, it is tiring work. It is for these reasons that the midwives have passed a small tube into your baby's tummy via his nose. They are then able to feed your baby safely without her becoming tired. As your baby grows she will mature and master feeding for herself. She will also become stronger and be able suck without becoming overly tired.

Not a lot of information is known about how babies learn to breast or cup feed or when is the best time to offer a baby a breast feed. Many factors may influence feeding and currently the midwives consider those they feel to be important. My research aims to look at many more factors and so enable midwives and parents to foster breast feeding in premature babies. Your baby will receive no different care or treatment than any other baby. The only difference is that she will be monitored before, during and after her feed.

If you decide to let your baby take part in the study, I will be involved in offering information and support to you and in to monitoring your baby during feeding. This will happen only when the nursery midwives decide your baby is ready for a breast feed; then monitoring will take place weekly until your baby is able to feed completely from you. To monitor your baby I will wrap a small probe around her foot and place a small pressure sensor button over her clothes. Whilst she is feeding I will place a stethoscope onto the side of her neck and listen to her swallowing; sucking will be monitored by placing a small pressure sensor button under her chin. Because babies are very different it is difficult to say how many times your baby will be monitored but I can assure you, by taking part in the study your baby will not stay any longer in hospital and you may at any time withdraw from the study without affecting your baby's care.





Appendix Figure 1 Pilot data validating jaw movement against intra oral pressure monitoring